

PITMAN'S AUTOMOBILE MAINTENANCE SERIES

AUTOMOBILE ENGINE OVERHAUL

A PRACTICAL HANDBOOK FOR SERVICE AND
MAINTENANCE ENGINEERS AND ALL
CAR OWNERS

BY

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PREFACE TO THIRD EDITION

THE demand for another edition of this book has afforded an opportunity to include information on new methods, tools, and equipment for the maintenance and servicing of car engines, whilst at the same time deleting some of the matter relating to engines that are going out of use.

The limited supplies of post-war model cars have resulted in the retention on the roads of a large proportion of pre-war cars, some of which would normally have been withdrawn from service. It is for this reason that certain information relating to pre-war model cars has been retained in the present edition.

The new or additional matter in this book includes that concerning cylinder and liner wear and reconditioning, piston and piston ring replacements, measuring gauges, the salvaging of worn components, e.g. valves, pistons, crankshafts and camshafts, new bearing boring machines, crankshaft reconditioning machines, stud removal methods, lubrication system and radiator maintenance, the road testing of reconditioned engines, etc.

In the course of the revision, several pages and 34 new illustrations have been added.

A. W. JUDGE.

FARNHAM, SURREY.

PREFACE TO FIRST EDITION

THE present volume is one of a series of inexpensive handbooks intended for the use of the motor engineer, mechanic, owner-driver, and engineering student concerned with the overhaul, maintenance, and tuning of motor vehicle engines.

It deals with the subject in an essentially practical manner, giving a number of useful methods, hints, tuning notes, and fitting instructions based upon the author's experience, over a fairly long period, with automobiles.

It is realized, however, that it is impossible in a small book of this nature to cover the wide subject of engine overhaul and maintenance in any detail, so that the information given is necessarily somewhat abridged, although it should nevertheless prove a helpful guide and reference to those concerned with the subject.

Special emphasis has been given to the location and remedy of the various faults likely to be met with in connexion with the engine as a unit; to the individual components of the engine, and the ignition system and carburettor.

Realizing, also, the advisability of employing labour-saving tools and equipment when undertaking engine repairs and adjustments, an appreciable amount of space has been devoted to the description and illustration of these items

Mention should also be made of the somewhat comprehensive index that has been included with the object of assisting the reader to look up any particular subject in the minimum of time.

A. W. JUDGE.

FARNHAM, SURREY.

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CHAPTER I

GENERAL INFORMATION ON OVERHAULING

THE modern motor vehicle petrol engine, if properly maintained, will operate for relatively long periods before a thorough overhaul becomes necessary. The maintenance attention necessary in such cases consists in regular lubrication with suitable grades of oil; adjustments of items such as valve tappets, timing chains, dynamo belts, pump glands, ignition gaps; and periodical decarbonizing, valve re-grinding, oil changing, filter cleaning, and similar operations.

On the other hand, if an engine has been neglected or run for appreciable periods without the proper maintenance attention, its useful life, before overhaul becomes necessary, will be seriously curtailed. Or again, if a new engine has been overloaded or operated at high speeds before the various bearing surfaces have had the opportunity to become properly bedded down, then excessive wear will no doubt occur at a much earlier stage.

It will thus be apparent that one may have two engines of identical design and materials, one of which has been carefully handled whilst the other has been neglected, so that the latter may require overhauling at a much earlier stage than the former.

It is therefore not possible to lay down any hard and fast rules regarding the definite periods, number of hours or miles run before petrol engines should receive a thorough overhaul.

The question of engine design must also be taken into consideration, for it is possible in the more expensive makes to introduce certain features, such as hardened cylinder liners, valve seating inserts, valve guide sleeves, chromium-plated valve rockers, tappets and crank journals, gudgeon pins, etc., which will greatly reduce the rates of wear of these important components.

The conditions of usage also affect the useful life, since of two identical engines properly maintained one may work normally under light loads while the other may be

constantly operated under full throttle conditions. Thus, if the engine is fitted to a car which is driven normally at moderate speeds it will evidently remain much longer in good condition than one employed in a car driven at high speeds or used regularly in very hilly districts.

Symptoms of Engine Wear. In view of the previously emphasized difficulties of establishing any definite rules concerning car-running periods and corresponding overhauls, it becomes necessary to determine these from actual symptoms exhibited by the engines themselves.

The more important symptoms that the owner, motor mechanic, or engineer will look for include the following, namely: (1) *falling off in performance*; (2) *excessive oil consumption*; (3) *increase in engine running noises*. Other associated indications of the necessity for a thorough overhaul include *loss of compression, overheating, and knocking due to faulty combustion conditions*. The emission of smoke from the exhaust pipe is another symptom of wear within the engine, as will be explained later.

(1) *Falling Off in Performance.* Assuming that the engine is still in the car or motor vehicle, it may be noticed that—as compared with its normal performance—the vehicle shows a falling off in its acceleration and maximum speed on the level. Further, it will not climb hills quite so well, an earlier gear change being necessary. Assuming that the transmission is in satisfactory order, that the brakes are not binding and the carburation and ignition in good condition and adjustment, this diminution of engine power may be put down to wear of the pistons, cylinders, valves, etc.

(2) *Excessive Oil Consumption.* When it becomes necessary to replenish the engine sump at more frequent intervals and no signs of oil leakages from the engine joints, pipe unions, timing case, or clutch pit are evident, this is a sign that oil is getting past the piston into the upper part of the cylinder, owing to relative wear of the piston (with its rings) and the cylinder barrels. The oil which thus escapes is burnt with the petrol and air charge, so that it becomes lost so far as the lubricating system is concerned.

A sure sign of worn pistons and cylinders is a continuously smoky exhaust, assuming the engine has not been

over-lubricated owing to too much oil in its sump or that an inferior grade of oil has not been employed.

Another safe indication of engine wear is to allow the engine to idle for a time and then to open the throttle whilst someone watches the exhaust pipe outlet; if excessive smoke occurs this shows that oil is getting past the pistons.

Yet another test is to coast down a hill with the transmission turning the engine, i.e. without declutching. Then, upon depressing the accelerator at the bottom of the decline smoke will be expelled from the exhaust pipe. An

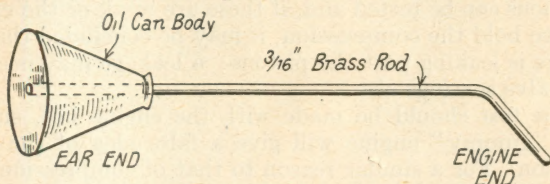


FIG. 1. A HOME-MADE STETHOSCOPE DEVICE

observer on the road or in a following car will readily verify this.

(3) *Increase in Engine Running Noises.* While the modern petrol engine in good condition is normally fairly quiet, as the working parts begin to wear the engine becomes noisier. Typical causes of such noises include the timing gears or chains, valve tappets, pistons and cylinder walls, connecting-rods, big-end and gudgeon pin bearings. In the case of the timing gears, any appreciable wear causes backlash; this in turn results in tooth impact noises when the engine is accelerated or slowed down. The source of such noises can sometimes be located by direct inspection and testing for backlash, but a quicker method is to employ some form of sound amplifier, such as a doctor's stethoscope.

A simple knock detector can be made from the base of an oil-can to which a metal rod is soldered or riveted as shown in Fig. 1. If the free end of the rod is held against different parts of the engine while it is working and the ear held near to the base end of the oil-can, any engine noises are magnified and the part of the engine from which they emanate quickly ascertained—since the noise is greatest

the nearer the rod end is brought to the source. In this manner, timing gear, tappet, small and big-end connecting-rod noises can readily be detected.

(4) *Loss of Compression.* Since the result of wear between the pistons and cylinder walls is to cause an increase in the clearances between these parts, when the mixture is compressed in the cylinders there will be a tendency for some of the charge to leak past the pistons into the crank chamber.

If, therefore, the engine is turned slowly with the starting handle (with the ignition switched off), the state of the compressions can be tested and, if these are weak or the engine fails to hold the compression, it may be concluded that the charge is leaking past the pistons; a leakage may occur at the valve seatings also.

This test should be made with the engine hot, since a cold "gummy" engine will give a false idea of the compression. For a similar reason to that of compression loss, part of the burning and burnt gases will blow past the pistons so that the gases—usually of a smoky nature—will issue from the crankcase breather or oil filler orifice. The suspected engine should, therefore, be watched for this effect.

Dilution of the lubrication oil at more frequent intervals is another indication of piston blow-by due to the same cause.

Overheating Effects. Although engine overheating may be due to other causes, including faulty radiator or cooling system, too rich or too weak mixture from the carburettor and too early or too late ignition timing, it is also caused by excessive cylinder wear or carbon deposit, faulty valves and their seatings. If, therefore, the former items have been verified, it may be assumed that the latter causes are associated with engine wear and the necessity of an early overhaul.

The Usual Overhaul Periods. An engine which has been carefully maintained in accordance with the manufacturer's instructions, in the matter of lubrication, decarbonizing, valve-regrinding, tappet adjustment, etc., may be expected to run for a period of at least 25,000 miles before it becomes necessary to dismantle it for major

operations such as fitting new piston rings, reboring the cylinders, truing valve seats, taking up clearances in the big-ends and main bearings.

The periods before reboring is necessary depend upon the design and kind of metal used for the cylinders. Thus, the ordinary "straight" cast irons hitherto employed usually wear more quickly than the alloy cast irons (nickel chrome) and therefore will require reboring at shorter intervals, namely, from about 25,000 to 30,000 miles, with new pistons and rings to suit. The alloy irons under normal conditions will give mileages up to about 50,000 or so before attention is necessary, although it is certainly advisable to fit new piston rings at an intermediate stage.

The best cylinder materials for minimum wear include the hardened alloy cast-iron ones and Nitalloy; these materials are employed for cylinder liners and usually give from about 70,000 to 100,000 miles of use before replacement.

The Principal Items of Attention. Apart from the question of general overhaul, it is of interest to consider the engine unit components which require the most attention, so that the motor engineer in planning his workshop equipment may make suitable provision.

In this respect, the experiences of the Royal Automobile Club in the matter of breakdowns on the road may be of interest, since the data supplied from this source represent a careful analysis from many thousands of road stoppages through mechanical failure taken over a period of several years.

The results, over a period of five recent years, show that about 50 per cent of all the breakdowns were due to the power unit. Analysing these breakdowns, it is shown that these were made up of 26 per cent due to the engine, 20 per cent due to ignition troubles, and 4 per cent to carburation causes.

If now we consider the causes of the engine trouble and their frequency, as expressed by percentages, we have the interesting analysis shown on page 6.

The chief cause of engine trouble was that of seized pistons, broken rings, and scored cylinders. Broken valves and springs were another frequent source of trouble.

In regard to carburation causes, these have more recently

ANALYSIS OF ENGINE TROUBLES

The cylinders and pistons	40.0
The valve mechanism (including the camshaft, valve tappets, and timing gear)	9.0
The valves	5.5
Lubrication system	9.5
Water circulation system	10.0
Crankshaft	2.5
Miscellaneous causes	23.5
	100.0

shown a tendency to increase, owing to the more complicated designs of carburettors.

Apart from these details, other causes for breakdowns with which the motor engineer may be concerned include those due to road accidents and to the effects of the cooling system water freezing in the cylinder jackets, pump, and radiator. In addition there is usually a more or less regular number caused by neglect to fill the cooling system, omission to replenish the oil in the sump.

In regard to the engine items of attention, Fig. 2 illustrates some of the parts which, sooner or later, will require servicing or replacement.

Typical Example of Worn Engine. In the case of a well-known make of 6-cylinder, 14-h.p. overhead valve car engine which, after a period of just under 40,000 miles, was stripped down for examination and overhaul, the following items were found to require replacement or overhaul. The engine had been properly serviced during its working period, e.g. cylinders decarbonized every 7000 miles, valves re-ground, oil changed at 4000 miles intervals, etc.

Cylinders. The bores were found to have worn slightly oval and tapered, being about 0.015 in. greater in diameter at the top piston ring T.D.C. position than at the B.D.C. position. The cylinders were rebored with a tungsten carbide cutter and honed to 0.030 in. oversize. New oversize pistons were fitted.

Pistons. These were of the steel-skirted aluminium alloy type. The steel skirts of three of the pistons were cracked and the piston ring grooves badly worn.

Valves. In fairly good condition, requiring only regrinding

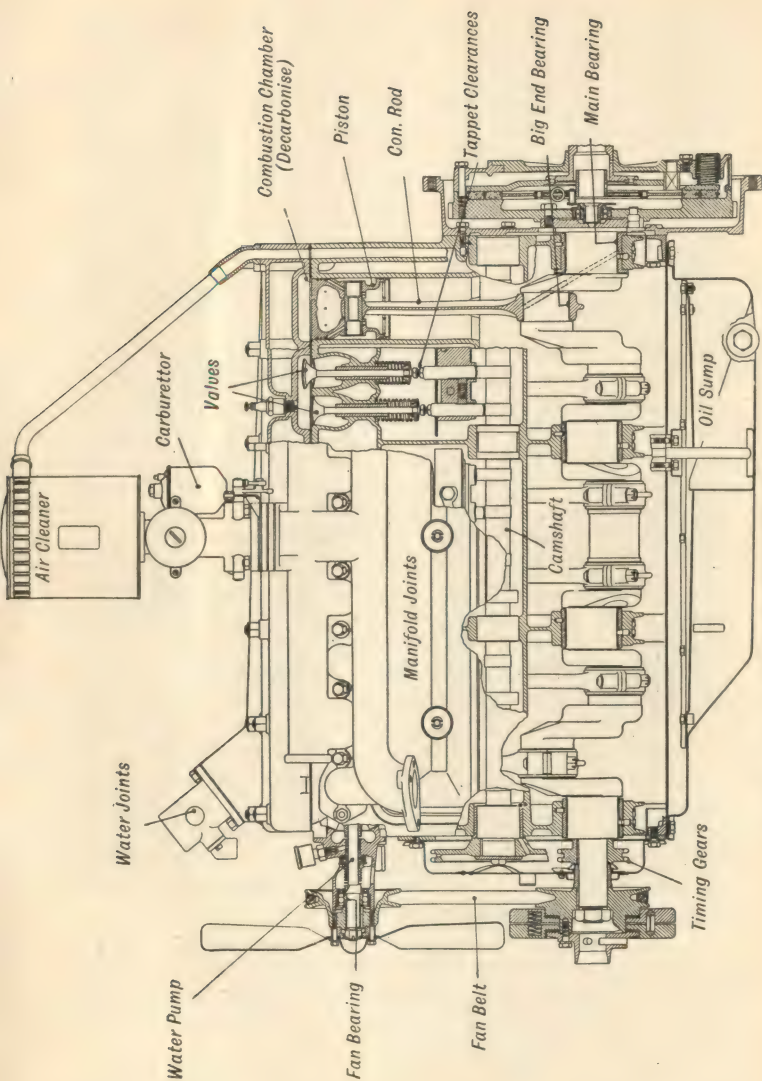


FIG. 2. SOME ITEMS OF ENGINE MAINTENANCE ATTENTION

and new valve springs were fitted. The valve guides were in fairly good condition.

Cams. These were slightly worn on the lifting faces, but still satisfactory for another 50,000 miles, at least.

Timing Chain Drive. Both the chain sprockets and chain were worn appreciably, the chain showing stretch effect. New sprockets and chains were fitted.

Crankshaft. The journals were slightly scored and generally of rougher surface than considered satisfactory. Slight oval wear was found. The crankshaft was reground and the big-end and main bearing were remetalled and bored out to suit.

Flywheel. The teeth on starter ring were badly worn in one place. As the ring could not be rotated and bolted up in the next best engagement position on the flywheel, a new unit was fitted. The clutch plates were also renewed.

Gaskets, etc. New cylinder head, inlet manifold, and exhaust gaskets were fitted; also new hose connections and rubber-fabric water-joint washers.

Engine Mounting. The rubber block mountings were found to have become compressed too much and the rubber showed signs of perishing, so these were renewed.

Sparking Plugs. New plugs were fitted; this is always considered necessary with a rebored engine.

Repairs or Replacement. When an engine part becomes worn sufficiently to necessitate attention in order to maintain the efficiency of the engine, the question often arises whether it is better to recondition or to replace the worn item.

In many cases it is quicker and cheaper to recondition the part provided the necessary equipment is available. Thus, it will usually be found that such items as the valves, camshafts, crankshafts, and the big-end and main bearings can be reconditioned far more cheaply than they can be replaced under normal conditions of wear.

On the other hand, if a valve has become "burnt" owing to neglect in the matter of valve stem clearance, it is obviously better to fit a new valve. Or again, if the valve stem has worn appreciably a new valve should be used, or carburation troubles will occur.

Such items as gaskets, piston-rings, locking tab washers, stretched timing chains, gudgeon pins and small-end

bushes, worn cotters, etc., should always be replaced. The condition of the mating members must, however, be considered when making replacements, for if these are worn then both members should be replaced. Thus, it is usually necessary to replace both the valve and its guide where serious valve stem wear has occurred; the gudgeon pin and small-end bush should, for similar reasons, both be replaced. In some cases, but not as a general rule, the timing chain sprockets may need replacing when new timing chains are fitted.

Equipment and Tools. The equipment of the motor repair workshop will depend upon the nature of the work that is to be undertaken. For ordinary maintenance and top overhaul work a fairly simple tool outfit is all that is required; the better tool-kits supplied with new cars will usually suffice for such purposes. A few additions, however, will extend the scope of the work that can be carried out. Thus, we should recommend such items as a set of files, hand-drilling machine of the two-speed pattern, set of box spanners, pair of tinman's snips, blow-lamp, set of Whitworth and B.S.F. taps and dies, gas-pliers, valve grinding tool, valve spring compressor, set of flat and half-round scrapers, hacksaw, and special spanners for hub caps, sparking plugs, etc.

For general overhaul purposes a full set of engineer's hand tools will be needed, together with special tools designed for different purposes where time and labour can be saved; some of these are described in the appropriate sections of this book.

Garage workshop equipment should include a screw-cutting lathe of 4½ in. to 6 in., sensitive drilling machine, power grinder, air compressor plant, portable electric tools, jacks and lifting tackle, small forge welding plant, sheet metal working machines for body and wing repairs, etc.

Where routine work includes cylinder reconditioning, the equipment should include cylinder grinding, honing or boring machines, valve seating tools, valve grinding machines, connecting rod boring tool, crankshaft truing tool, main bearing boring bar type tool, etc. A small milling machine of the horizontal pattern will also be found very useful for making special parts.

CHAPTER II

DISMANTLING THE ENGINE

WHEN it is found necessary to dismantle a motor vehicle engine following the results of a diagnosis on the lines recommended in the previous chapter—or in the event of a breakdown—the general procedure to be observed is as follows.

Assuming that the engine is in its chassis, the first operation is to disconnect every external attachment so as to leave the engine free for removal by a suitable gantry, block and tackle, or similar lifting device.

Disconnecting External Components. First empty the radiator and cylinder jackets. If a water pump is fitted, this will usually be found to have a drain cock, which should also be opened.

Disconnect the rubber hose connexions at the top and bottom of the cylinder block. If these are gently prised around their pipes and a little soapy water inserted, they can be worked off without damaging the rubber, and then used again. Mark the hose and clips before final removal to ensure correct order of replacement. It is generally advisable to *remove the radiator bodily* so that one can work more conveniently on the engine.

Next, disconnect all external electrical cables to the ignition unit, dynamo, motor, sparking plugs, etc.

Then remove the carburettor, since this may become damaged when lifting the engine. The petrol tap is first shut off and the petrol pipe to the carburettor then disconnected. Then the controls to the carburettor, namely, the throttle and air choke, should be taken off.

The next step is the disconnexion of the *exhaust pipe* from the exhaust manifold; the former is held by two bolts and nuts so that the removal of these will free the exhaust pipe.

Next, disconnect the *oil pressure pipe* leading to oil gauge on the dashboard.

If a radiator thermometer is fitted to cylinder water jacket, this must be disconnected at the engine end.

Having reached this stage, make a careful inspection to ensure that there are no other rod, cable, electrical, or pipe connexions to the engine.

It now remains to disconnect the engine from the transmission.

If the gearbox is a separate member with short intermediate shaft, it can be left in position in the chassis and the forward coupling joint of the shaft broken.

If the gearbox is of the more common engine unit pattern, it can be removed bodily with the engine, after disconnecting the front universal coupling of the propeller shaft, the brake control joints, and the speedometer coupling on gearbox. It will then be found more convenient to disconnect the clutch and gearbox with the engine on the bench or stand.

Having freed the engine unit from its external connexions it now remains to undo the engine holding-down nuts and—in the case of the unit gearbox—the gearbox holding-down nuts. The bolts can then be knocked out, using a copper drift, when the engine is ready for lifting out of the chassis.

Before moving the engine, however, *the positions of the engine lugs* on the chassis frame cross-members should be marked with a scriber; this will obviate the necessity for re-alinement of the engine when it is replaced in the frame.

It will not usually be necessary to remove the dynamo or motor from the engine before the latter is lifted clear of the chassis.

In some cases, however, it will be found necessary to remove the gearbox from the combined engine unit before taking the engine out.

Lifting the Engine Out. For the smaller sizes of car engine the owner-mechanic will find a block and tackle arrangement convenient. If a stout pole—such as a piece of scaffold pole—be lashed in position to the roof rafters of the garage; this can be used for fixing the upper hook of the block and tackle to. Then, after lifting the engine out of the chassis the latter can be pushed out of the way and the engine lowered on to a wooden stand or bench.

Fig. 3 illustrates a method of lifting a Vee-eight engine, using block and tackle, with a special plate having a chain and double sling of wire rope below.

The engine should be lifted with a double hemp rope, wire rope, or chain sling in the manner indicated in Fig. 4;

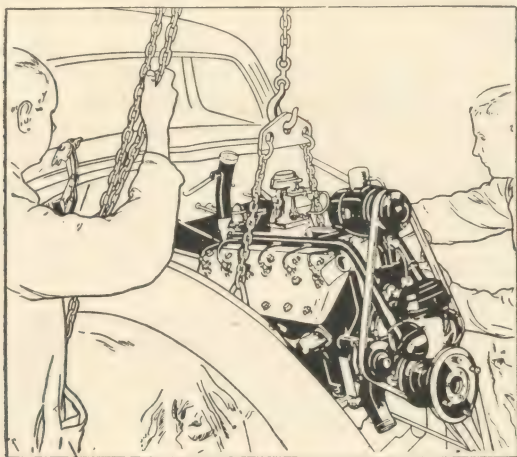


FIG. 3. LIFTING A LARGE ENGINE OUT OF CHASSIS

care should be exercised when adjusting the sling not to injure any of the engine components.

For garages where engine repairs are carried out as regular routine practice, some form of floor crane, such as the type shown in Fig. 5, should be employed, since with this engines can quickly be hoisted and the crane with the engine transported to any part of the garage workshop.

The H.F. Jackrane illustrated has a total height of 9 ft. 3 in. and gives a vertical lift of 7 ft. It is provided with four roller wheels, those at the pillar end being of the spring-loaded castor type. The jib of the crane is arranged to extend well over any car or commercial vehicle engine, while the pillar is quite clear of the chassis.

In case of emergency, a temporary lifting rig can be made by lashing three shortened poles into the form of a

tripod and attaching the upper hook of a block and tackle to the rope or wire lashing.

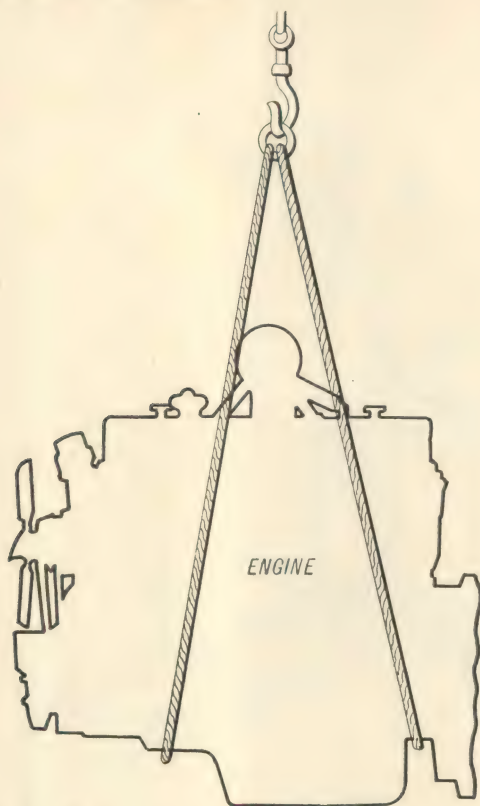


FIG. 4. METHOD OF SLINGING AN ENGINE FOR LIFTING OUT OF THE CHASSIS

NOTES ON DISMANTLING ENGINES

The following notes and hints are based upon experience in disconnecting and dismantling motor engines—

(1) All important mating parts of the engine or its accessories should be marked with a centre punch, file, or chisel to ensure correct reassembly.

(2) When disconnecting carburettor or ignition control mechanism, always replace all bolts, pins, and split-pins in their original positions in one of the two members afterwards.

(3) Care should be taken not to damage carburettor,

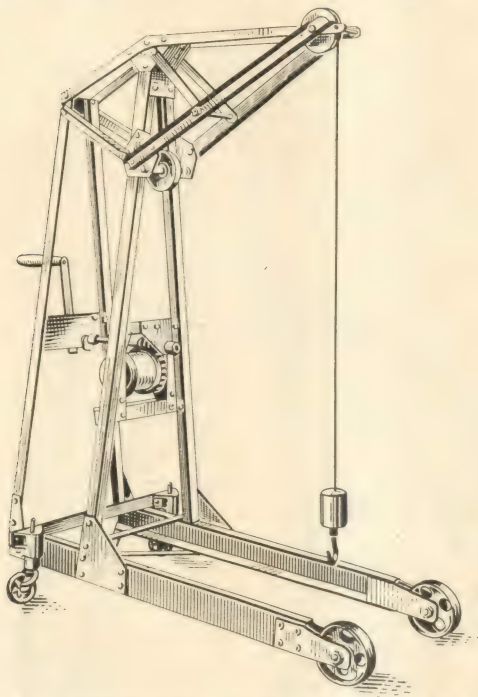


FIG. 5. A CONVENIENT GARAGE CRANE (HARVEY FROST)

inlet, and exhaust manifold gaskets as these can generally be used again. Water gaskets, however, being made of an asbestos composition, should be replaced with new ones either as spares or cut out of the sheet.

(4) All parts taken off the engine should be placed in a box; this will obviate the loss or damage of any parts. The smaller items such as nuts, washers, etc., should be kept in a small box.

(5) It is a good plan, after removing components, to clean them before proceeding with any other work on the engine. Thus, all nuts, washers, valve cotters and springs, circlips, etc., may be placed in a bowl containing paraffin, in which they can be scrubbed with a stiff brush.

(6) Bolt or stud threads should be cleaned with penetrating oil or paraffin and their nuts screwed up and down; any tight nuts should be tapped out and damaged threads on the male members remedied with dies or die-nuts.

(7) All machined joint faces must be cleaned of jointing material and any burrs filed off with a smooth file; the latter should be kept flat on the joint face to avoid any rounding effect.

Engine Stands. After removing the engine from the chassis it should be mounted upon some kind of stand. This may be of the type built up from stout wooden members, or preferably of the pattern supplied by garage equipment firms such as Messrs. Harvey Frost, Weaver, Bradbury (G.E.), etc.

Fig. 6 illustrates a wooden trestle-type engine stand consisting of two longitudinal members upon which the engine bearers rest and four stout legs braced together by cross pieces and longitudinal stays near their lower ends.

The G.E. engine stand shown in Fig. 7 is of all metal construction, of convenient form to take various types of engine. It is provided with a swivelling device for the engine bearers, whereby the complete engine can be turned into any angular position and, by means of friction clamps, locked into these positions. It is thus possible to work conveniently on the engine in any required position of the latter. The engine stand is provided with rollers for transport purposes.

Dismantling the Engine. Assuming that the engine has been removed bodily from the chassis and mounted on an engine stand, the dismantling should be carried out as follows.

With the engine in its normal vertical position first remove the plug from the bottom of the oil sump and drain out the oil; this operation might, however, have been done before commencing the disconnexion work in the chassis preferably while the engine was hot.

Next, disconnect the inlet and exhaust manifolds in order to render the inlet and exhaust ports accessible for cleaning. Undo the cylinder head nuts, after removal of the sparking plugs, water connexions, or other similar items. In the case of overhead camshaft engines, in some designs, the camshaft must first be removed.

The cylinder head nuts should first be slackened off in a

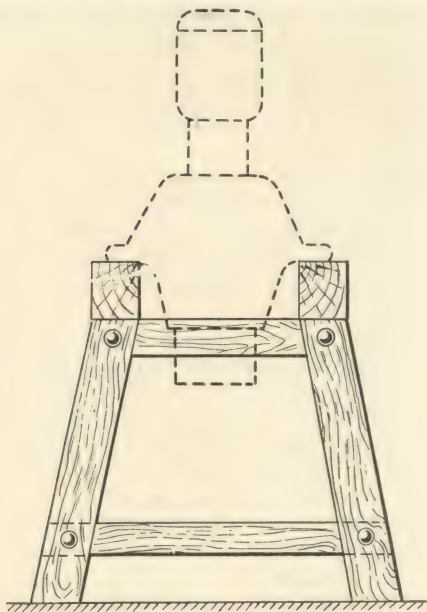


FIG. 6. BUILT-UP ENGINE STAND

definite order, commencing at the centre and working, as it were, spirally outwards. Once the nuts have been unscrewed by about a turn, they can then be taken off in any order.

Having made certain that all of the cylinder head nuts have been removed, take off the head itself. Generally, owing to the jointing material and burnt oil on the gasket and studs, the head will be found to be stubborn in regard to its removal. It is then better to use cylinder

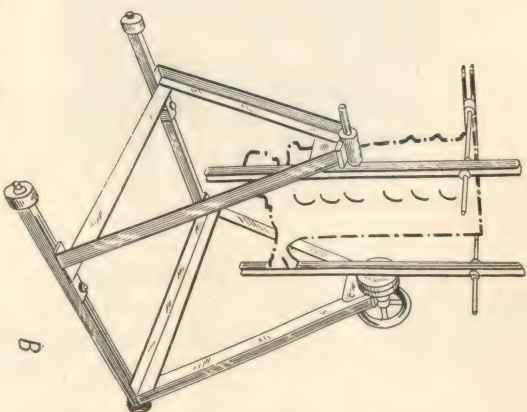
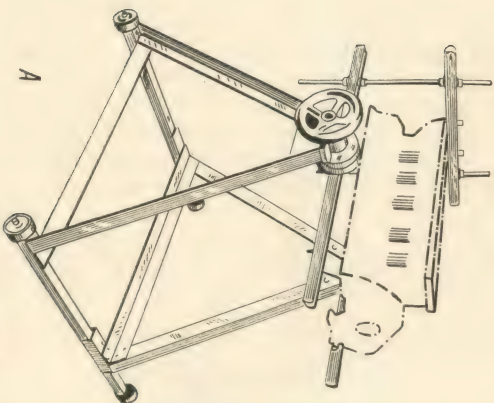


FIG. 7. THE G.E. ENGINE STAND

A—Engine Horizontal B—Engine Vertical

lifting tools of the type shown in Fig. 8; these can be made from old sparking plugs or may be purchased from garage accessories firms.

Sometimes the top water outlet pipe will afford a firm hold for the cylinder head. If, now, the sides of the head be tapped with a wooden mallet or raw-hide

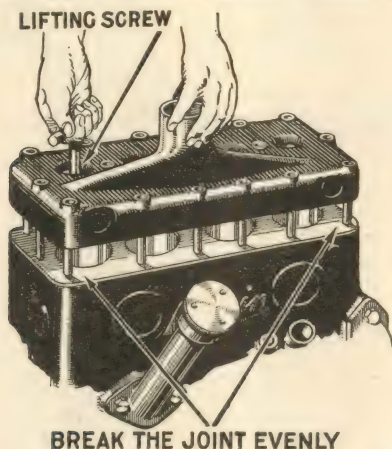


FIG. 8. LIFTING THE AUSTIN CYLINDER HEAD

hammer and then the head itself is pulled and pushed with the lifting devices, so as to give it a rocking effect, this will invariably break the joint and allow the head to be lifted off.

Sometimes projecting lugs are left on the lower part of the cylinder head for the purpose of assisting one to break the joint by the insertion of a suitable lever. In other cases, when the sparking plugs are in position, the joint may be started by turning the engine over its compression, using the starting handle, so that the compression will tend to lift the head.

It is inadvisable to use a wedge or screwdriver blade in order to break the joint, as there is then a risk of damaging the machined faces and thus causing possible compression leakage upon replacement; further, the copper-asbestos gasket will invariably be ruined by this method.

Having taken off the cylinder head, the gasket should be carefully lifted off, using a knife blade to loosen it all round. If undamaged, it may be used again, provided it is lightly coated with a suitable jointing compound or a high melting point grease.

All nuts should be replaced on the cylinder studs.

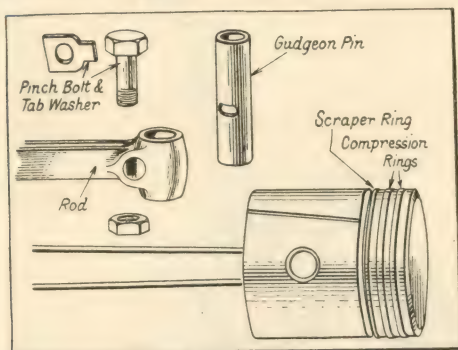


FIG. 9. PISTON COMPONENTS OF ARMSTRONG-SIDDELEY ENGINE

Dismantling Pistons and Connecting-rods. The method, which is applicable to engines in the chassis as well as to those on the bench or stand, is as follows—

First unscrew the nuts of the crankcase sump bolts and take off the sump.

Remove split-pins from connecting-rod big-end nuts, and with a box spanner remove the nuts and locking washers.

Before removing the caps make sure that these and the corresponding connecting-rod members are stamped with the numbers of the cylinders; all the parts should be marked on the same side to ensure reassembly the right way round.

It is best to take off one bearing cap at a time, care being exercised in removing the shims between the bearing halves that each set is tied to its proper side of the bearing cap. Similarly the big-end cap nuts should be replaced each on its proper bolt after removing same from the connecting-rod.

To remove the piston it is necessary to test whether the

connecting-rod big-end portion will pass up through the cylinder barrel. If so, the piston and rod can readily be withdrawn bodily, taking care, however, not to scratch the cylinder barrel.

In most cases the big-end will not clear the barrel so that it is necessary, first, to push the connecting-rod up

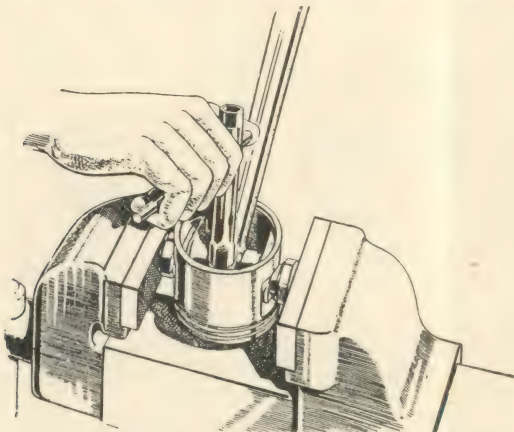


FIG. 10. REMOVING THE MORRIS GUDGEON PIN

as far as it will go and then to take out the gudgeon pin, after first removing the spring clips securing it in place. The piston is then pulled out from the top after taking the connecting-rod from below through the sump opening.

Before removing the piston see that it is marked with the number of the cylinder and the front or back side also, to ensure that it goes back in the correct position in the cylinder barrel.

Sometimes the gudgeon pin is locked by means of a hexagon-head screw into the split small end of the connecting-rod, as on the Armstrong-Siddley and Morris Eight engines. With this type the connecting-rod and its piston can be removed through the oil sump opening and the piston held in a vice, using a pair of shouldered plugs—as shown in Fig. 10—for holding the gudgeon pin and piston without risk of damage.

The Timing Gears. After removal of the timing case, if there is any necessity to remove the timing gears, as for camshaft removal, an examination of the timing gears or sprockets will indicate the correct procedure. The idle gears will readily slip off their pins, but the gears on the crankshaft, camshaft, or other shafts will require the use

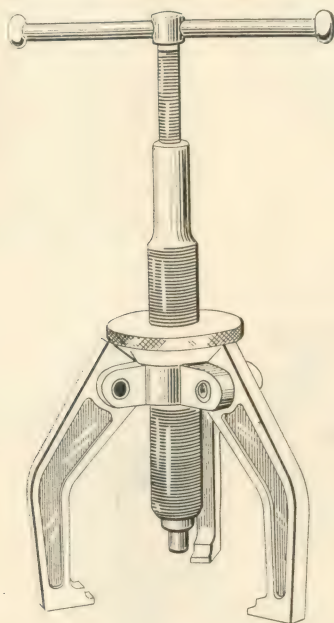


FIG. 11. A USEFUL GEAR WITHDRAWAL TOOL

of a pulley-drawing tool (Fig. 11), since they are tight fits on the shaft ends.

The pulley and sprocket withdrawal tool shown in Fig. 11, known as the "Apkaway," operates upon the hydraulic principle, whereby the right-hand rotation of the centre screw produces a steady pressure of about 20 tons on the centre plunger seen between the three claw arms; the latter are set to the required distances apart by means of

the milled screw which has a large cone bearing on the upper ends of these hinged levers.

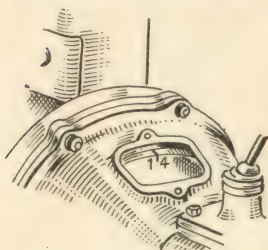


FIG. 12. TIMING MARKS ON FLYWHEEL

Timing Gears, Correct Meshing.

It is important, before dismantling an engine, to ensure that there will be no difficulty in regard to the correct valve timing when timing gears are reassembled, by marking the top dead centre (T.D.C.) of No. 1 piston, i.e. the one nearest the radiator, and also by marking the meshing positions of the gears.

Generally, the flywheel rim has a mark (Fig. 12) which is brought opposite to a fixed mark on the crankcase to give No. 1 T.D.C. position. Otherwise the latter position can be ascertained by removing the sparking plug and observing the piston's movement with

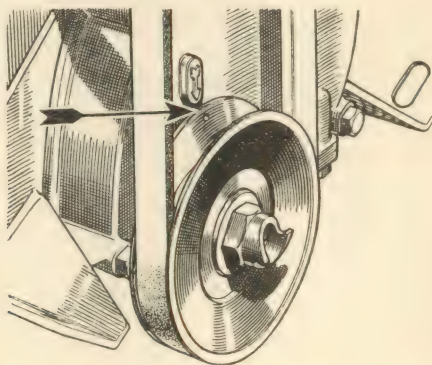


FIG. 13. T.D.C. MARK ON MORRIS ENGINES

a small pea-lamp inserted in the plug hole—or by means of a piece of rod or wire. The flywheel rim and crankcase can then be marked with corresponding chisel cuts.

A simple method of checking the top dead centre position, used in the case of Morris engines, is illustrated in Fig. 13. A small hole is provided in the crankshaft pulley flange, which registers with the arrow seen above in Fig.

13, on the timing chain cover, when the crankshaft is in the top dead centre position for Cylinders Nos. 1 and 4.

It is now the usual practice to mark the teeth of meshing gears of timing wheels with a line or dot on the tooth of one wheel and a pair of lines or dots on the teeth of the meshing wheel as shown in Fig. 14. If, before dismantling the gears no such marks are found, they must be etched on the teeth, since the latter are much too hard to mark with a punch or chisel.

To etch the teeth, first warm them slightly with a blow-lamp and then coat the teeth to be marked with a thin

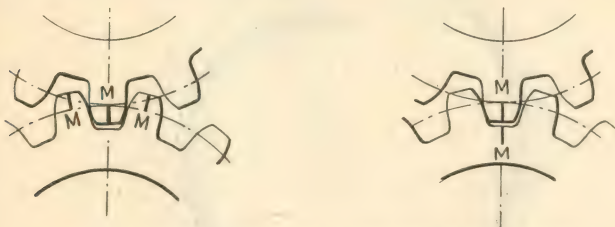


FIG. 14. TWO METHODS OF MARKING TIMING GEARS

layer of paraffin (or candle) wax. After hardening, cut the lines through the wax with a sharp tool and apply some nitric acid to the wax, when it will eat away the exposed metal.

The teeth may, however, first be marked with paint lines. After allowing the paint to dry, the gears are removed and taken to a bench where they can be etched more conveniently. Alternatively slight grooves can be ground with a knife-edge pattern grinding disk.

When timing chains are employed, one plan adopted by the engine manufacturers is to mark a pair of adjacent teeth on each of the crankshaft and camshaft sprockets in such a manner that, when a straight-edge is laid across the sprockets so as to join, the centres of the two pairs of lines lie on either side of the line joining the centres. Another method, used for overhead camshafts driven by chains direct from the crankshafts, is to mark the camshaft sprocket with a line which is brought opposite a fixed

pointer on the cylinder head rocker shaft portion. Then, when the piston of No. 1 cylinder is on T.D.C. and the camshaft sprocket mark is opposite the pointer, the timing chain is replaced and the valve timing is correct. On one

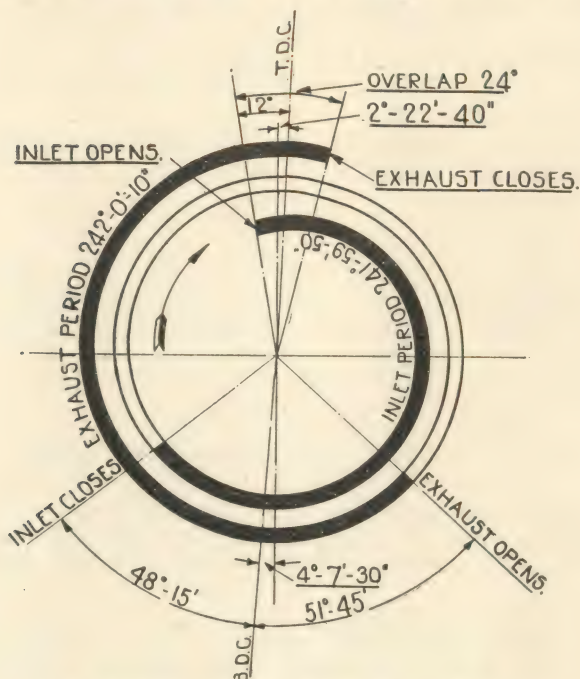


FIG. 15. TYPICAL VALVE TIMING CHART (MORRIS)

of the Wolseley models the camshaft sprocket has slotted holes where it is bolted to a flange on the camshaft, to allow the timing to be altered a little.

Checking the Valve Timing. Wherever possible the valve timing, after reassembly of the timing gear drive, should be checked against the manufacturers' valve timing chart or settings, which will usually be found in their instruction or service manuals (Fig. 15).

If the valve opening and closing positions are given

in degrees from the top and bottom dead centre positions, these can be converted into distances around the flywheel rim as follows.

First ascertain the exact length of the flywheel rim or perimeter by measuring this distance with a narrow flexible steel tape.

Alternatively, if the diameter is measured, then the perimeter can be estimated from the relation—

Flywheel circumference = $3.14159 \times$ diameter of flywheel.

To find the distance, d , from the T.D.C. mark corresponding to any valve opening angle, denoted by the letter A , in degrees (Fig. 16) the following relation holds—

$$\frac{d}{\text{Circumference}} = \frac{A}{360}$$

Thus if A is 15 degrees and the flywheel circumference is

30 in., then d will be $\frac{15}{360} \times 30 = 1.25$ in.

Cleaning the Components.

After dismantling, the components should be cleaned thoroughly to get rid of dirt,

oil, or grease before they can be examined or measured. For small parts, where only a limited number is concerned, a paraffin bath can be used, the parts being brushed or scrubbed with a stiff bristle brush to get rid of hard deposits.

For the larger components it is usual in small motor works to use a hot caustic soda bath for all steel parts; this solution should not be used for aluminium alloys since it has a marked chemical action—paraffin is recommended instead.

In the larger works special chemical degreasing plant is employed to clean motor components. Usually, the dirty parts are placed in a large perforated tray or wire basket and exposed within a tank-like container to the vapour of

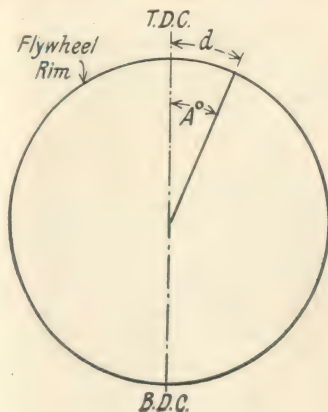


FIG. 16

the heated chemical solution. A typical example of the latter is trichlorethylene, which is used in the I.C.I. degreasing plant; it is a cheap and powerful grease solvent and is non-inflammable. A condenser enables the used vapour to be returned to the reservoir below the tray for further use.

There are now proprietary makes of cleaning powders and solutions on the market for degreasing dirty engineering components. The powder type is mixed with water and used hot. Degreasing solutions, such as Gunk, are used by spraying or brushing them on the components and then, merely rinsing the solution off with a pressure water jet; it is non-corrosive and does not affect wood, rubber, fabric, or cellulose enamels. It can be used in degreasing tanks many times over and lasts practically indefinitely.

When caustic soda solutions are used care must be taken not to get any of the solution on the hands or clothing as it exercises a strong caustic action.

Examining Engine Components. The cleaned components should be given a careful inspection for the condition of the bearings or working surfaces and any parts exhibiting excessive wear should be marked for replacement. Special attention should be given to the teeth of gear-wheels and sprockets; the presence of highly glazed areas, flats or burrs should be looked for, since these indicate excessive wear.

Valve stems and valve guides may be tested for undue clearance, valve seatings and faces for pitting and wear.

Pistons, cylinder barrels, gudgeon pins, connecting-rod bearings, crankshaft journals and main bearings should also be inspected and checked by careful measurement, in order to ascertain which parts should be reconditioned or replaced.

If new or spare parts are kept for the particular make of engine, these will afford a useful standard for comparing measurements.

In particular the valve tappet contact faces and valve cams should be checked for excessive wear.

CHAPTER III

DECARBONIZING

AFTER an engine has been in service for several thousand miles, as a rule it becomes necessary to remove the layers of hard carbon deposit on the piston heads, cylinder combustion chamber, and valve heads. This deposit consists chiefly of carbon derived from the lubricating oil which gets past the piston, together with carbon caused by running on excessively rich petrol mixture, and a certain amount of extremely hard siliceous matter from road dust—in cases where no air cleaners are employed.

The actual mileage at which an engine should be decarbonized is a somewhat variable factor depending upon the design of engine, its mechanical condition, nature of normal work done by it, quality and amount of lubricating oil, etc.

While under normal conditions of use a modern car engine will run for 4000 to 6000 miles before decarbonizing becomes necessary, an engine which has had a fairly long period of service, during which piston and cylinder wear have occurred, will require attention every 2000 miles or so. On the other hand, there are several cases of modern well-designed engines running for 10,000 to 15,000 miles before the presence of carbon deposit affects the performance.

The decarbonizing period is therefore generally gauged by the running of the engine, namely, by its tendency to "knock" or "pink" on hills or under heavy loads, whereas when in cleaner condition and with the same ignition timing and carburettor settings it would not exhibit these characteristics. This knocking in such instances is entirely a combustion effect caused primarily by the increased compression which, in turn, is due to the reduction in the volume of the combustion chamber owing to the thickness of the carbon deposit; the heat insulating property of this deposit also has a detrimental effect upon the combustion process.

The areas on which carbon deposits occur in petrol engines include the combustion chamber walls, piston crowns, valve

heads, sparking plug, under valve heads, valve posts, inside piston crowns, and behind the piston rings, as shown in Fig. 17, by the regions marked with the letters "C."

Methods of Decarbonizing. In order to decarbonize an engine in place on the chassis it is necessary to remove the cylinder head, after draining the water system. The method

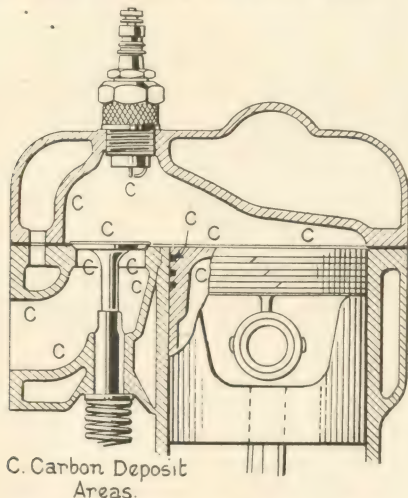


FIG. 17. LOCATION OF CARBON DEPOSITS

of removal of the head has been described in the preceding chapter.

It should here be mentioned that it is not advisable to remove the valves—whether of the side or overhead types—*before* decarbonizing, since the valves will protect their seatings from accidental damage by the carbon scraping tools.

Before attempting to scrape away the carbon, the various water openings in the cylinder block or head machined faces should be stopped up with soft paper or rag to prevent the carbon particles from entering. The cylinder bores should first be wiped free from oil and, with the starting handle, the crankshaft turned until one (or in four-, six-, and eight-cylinder engines, two) of the pistons is on its T.D.C.

As decarbonizing of the pistons proceeds, all loose deposits should be blown out of the other cylinders with an air jet, e.g. tyre inflation pump. An old piston ring can be inserted into the cylinders whose pistons have been decarbonized and pushed up close to the pistons, to prevent fine carbon particles becoming wedged between the top lands and the cylinder walls. This is recommended as the carbon deposit invariably contains *siliceous matter*, derived from road dust, which has *marked abrasive properties* on the soft aluminium wearing surfaces.

The carbon should be scraped off the piston crowns with a flat scraper which can either be bought or made from an old flat file. Care must be taken not to scrape off any of the metal of the piston crowns; with aluminium pistons this is of special importance.

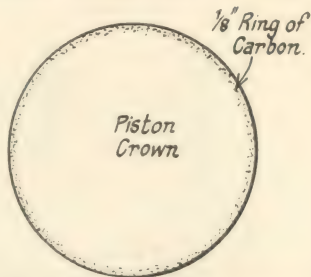


FIG. 18. RING OF CARBON LEFT AROUND EDGE OF PISTON

It is recommended by some car manufacturers that instead of scraping all of the carbon off the aluminium piston crowns, a ring of carbon (Fig. 18) should be left so as to prevent oil flow past the top piston land, for, normally, the clearance between the top ring and piston top is practically filled with carbon. An old piston ring can be used on top of the piston, the carbon being scraped away from inside the ring area. When one piston has been scraped clean, wipe over well with a rag soaked in paraffin; *under no circumstances employ emery cloth* to polish the piston crown. It is best to stuff a rag into the top of each cylinder barrel after its piston is cleaned and has descended on turning the engine crankshaft to bring the next piston to the top.

The *tops of the valves* (which in the case of side-valves should *both be closed* on the seats of the cylinder being dealt with) should also be scraped clean; similarly with the combustion surfaces around the valves and pistons.

The Cylinder Head. It is best to finish the cylinder block

and pistons before proceeding with the cylinder head decarbonizing. After the former has been done, a piece of clean cloth should be placed over the cylinder block to protect it from dust.

The cylinder head is more conveniently cleaned on a bench or box top, the carbon where hardest being chipped

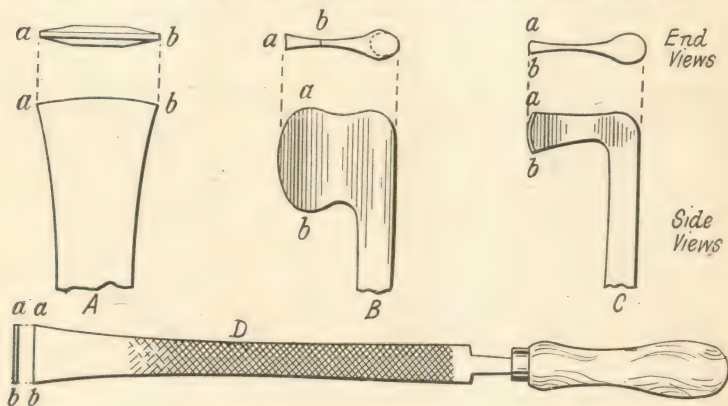


FIG. 19. SOME USEFUL CARBON SCRAPING TOOLS

- A = For slightly curved parts
- B = For radiused places
- C = For corners
- D = Flat scraper for piston crowns, etc.

In each case the scraping edge is denoted by *ab*

with a screwdriver or similar hard-edged tool. The softer carbon can be scraped off.

As the combustion chambers, formed in the heads, have rounded portions it will be advisable to use either a rotating wire bristle brush of the type shown in Fig. 20 or special curved edge scraping tools (Fig. 19). The electric motor-driven brush affords the quicker and more efficient method and should be used wherever possible.

When decarbonizing the head, the sparking plug holes should not be overlooked; the plugs should be taken out before commencing the decarbonizing operations.

After getting rid of the carbon, wipe over the surfaces with a paraffin-soaked rag, and then dry.

Other Decarbonizing Methods. While there is no doubt

that the carbon brush or scraping methods described are the most satisfactory, mention should be made of the chemical and oxygen methods which are sometimes used in cases where there is no time available for dismantling the cylinder head. Under such circumstances the valves cannot be reground as is usually considered necessary when an



FIG. 20. PORTABLE ELECTRIC MOTOR BRUSH FOR
DECARBONIZING

engine is decarbonized. The chemical method consists in injecting into each cylinder head through the sparking plug hole a special chemical in liquid form. The engine should be in a warm condition so that the liquid can act more efficiently. After standing for about twelve hours the carbon is loosened, so that upon starting up the engine it is blown out of the exhaust pipe.

The oxygen method, which is definitely an effective one, consists in burning out the carbon with a jet of oxygen. The piston is set on its top centre, with the engine in a hot condition, the radiator drained, and the petrol drained from carburettor—in order to avoid a fire. The oxygen is introduced by means of a copper pipe, through the sparking plug hole, and the burning started with a wax taper. The

carbon then burns away into carbonic acid gas and if the copper pipe is suitably manipulated all of the piston top and combustion chamber surfaces may efficiently be cleaned. Finally, when all combustion has ceased, the oxygen jet supply is momentarily opened full so as to blow any detached carbon particles out of the cylinder.

The British Oxygen Supply Company provides a special decarbonizing outfit for this purpose.

The time taken varies from five to ten minutes per cylinder and after the block has cooled sufficiently, the cooling water system is replenished and the engine can at once be started up.

Another recent method for quickly decarbonizing cylinder heads is to employ a shot blast nozzle which directs hard shot under pressure from a compressed air supply on to the carbon deposits.

A typical shot blast cabinet made for this purpose will decarbonize a cylinder head in three minutes.

CHAPTER IV

VALVE REMOVAL AND RECONDITIONING

AFTER decarbonizing the cylinder units the valves should be removed for inspection and, if found necessary, reconditioning of their bedding faces and also the valve seatings.

The method of removal depends upon the type of engine, i.e. whether of the side or overhead pattern.

Side Valve Engines. The method of removal consists in holding the valve heads securely, then compressing the valve spring with a suitable tool until the device holding the valve collar in place is exposed sufficiently to permit of its removal with the fingers, a pair of narrow-nosed pliers, or a special device supplied for the purpose.

There is a variety of valve spring compressors on the market, of which those supplied by the car manufacturers for their own engines and the universal types are the most suitable. In selecting such tools, preference should be given to those which embody devices for holding, or locking, the compressed springs in position, so as to leave the fingers free for removing the valve split collars, or cotters.

Fig. 21D shows a useful design of spring compressor suitable for light car engines, such as the Austin,* Hillman, and certain Morris models. The slotted portion is inserted under the valve collar and the finger screw engaged on the valve head and turned so as to compress the valve spring sufficiently to remove the collar retention device (whichever pattern is used, as shown in Fig. 22).

The Terry valve spring compressor (Fig. 21B) is another useful device which is sufficiently narrow at the forked ends to enable it to be inserted between the valve collar and tappet unit. It holds the spring compressed, and is equally suited to valve replacement.

The "Zim" spring compressor (Fig. 21A), which is suitable for Fords and similar types of engine, has a ratchet and pawl locking device; it is made of pressed steel and is easy to manipulate.

* See also Fig. 25.

Removing and Inserting Split Collars. Many valves in present use employ split conical keepers engaging with

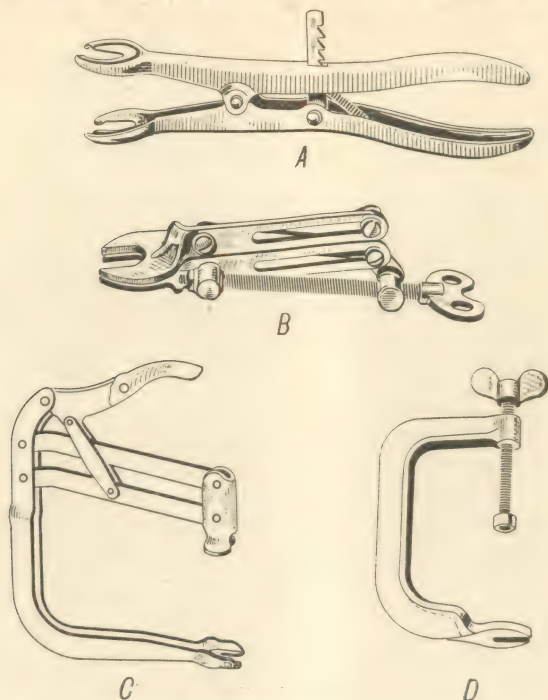


FIG. 21. TYPICAL VALVE SPRING COMPRESSORS FOR HOLDING SPRING IN COMPRESSED STATE

- A = Ratchet pattern
- B = Terry screw type
- C = Quick action valve head model
- D = Screw down valve head holding type

recesses turned in the valve stems and conical holes in the valve spring collars (Fig. 22).

These split keepers can readily be removed after holding the valve spring in its compressed condition, by pushing them out with a piece of wire or wooden strip.

To replace these keepers a special tool for holding each

half in its proper position should be used ; otherwise much time may be wasted in the attempt.

Fig. 24A illustrates the Terry split cotter holding tool

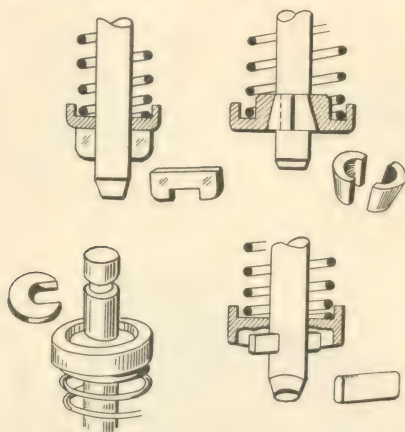


FIG. 22. VALVE COLLAR RETENTION DEVICES

which grips the two halves of the split cotter firmly and places them in position to receive the spring cap. It embodies, also, a self-locating spring cap which cannot tilt

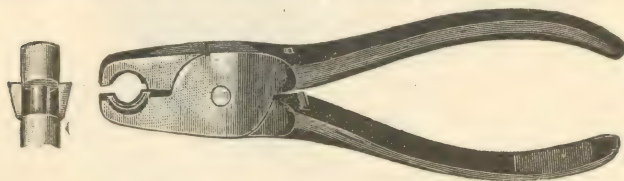


FIG. 23. TOOL FOR SPLIT CONICAL KEEPERS

to one side of the valve stem or foul the edges of the split cone.

The difficulty of extracting and replacing split cone cotters may be avoided and much time saved if these cotters are replaced with the Terry spring cone cotters of the type shown in Fig. 24B. It is provided with a tail piece holder and springs over the taper of the valve stem

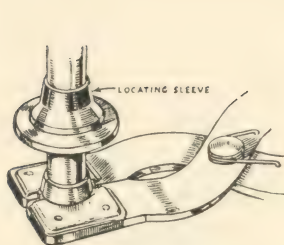


FIG. 24 (A)

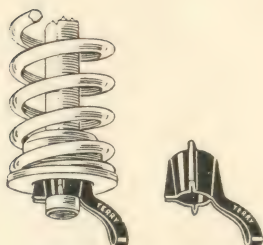


FIG. 24 (B)

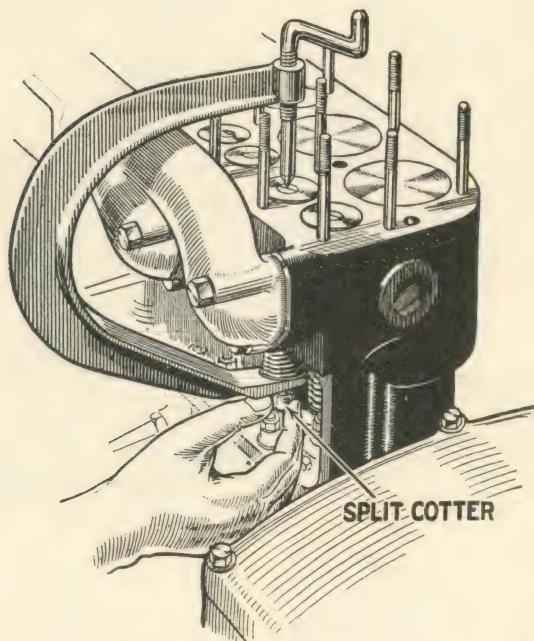


FIG. 25. REMOVAL OF CONICAL KEEPERS (AUSTIN)

and rests upon the boss. They take up little space and are readily removed and inserted.

In an emergency, however, each half of the keeper can be replaced as follows: Shape a strip of hard wood, about $\frac{1}{4}$ in. square, so that one end has a half-round shape corresponding to the outside of the split keeper. Next, smear a little stiff grease around the recess in the valve stem (after

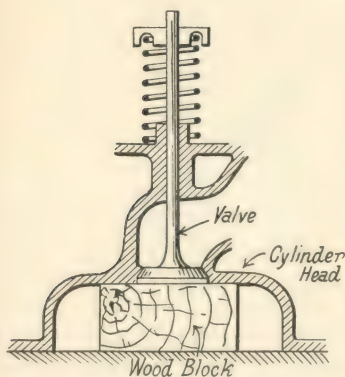


FIG. 26. REMOVING OVERHEAD VALVE

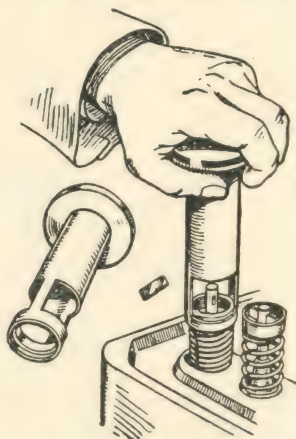


FIG. 27

the spring is compressed and held). Then daub some grease on the end of the wooden member and stick the split keeper on to this. The keeper will be held with sufficient firmness to enable it to be inserted into the valve stem recess; moreover, the grease on this will hold it in position. The other half of the keeper is similarly replaced and the valve spring and collar lowered on to the two halves.

Alternatively a screwdriver with a magnetized blade, or a specially shaped rod of steel magnetized at one end can be used to hold the split keepers; the grease on the valve stem will hold them in position.

Removal of Overhead Valves. As these valves are in the cylinder head, the latter can be supported on a stand or the bench so that the valves can be removed more conveniently.

It is necessary first to remove the rocker arms, or rocker shaft complete with its rocker arms; with certain types of overhead camshaft engines the camshafts must be removed before the valves become accessible.

The method of removing the valves is as follows. Place a suitably shaped block of wood in the combustion chamber (Fig. 26) to prevent the valves from moving when their springs are compressed, arranging the cylinder head so that

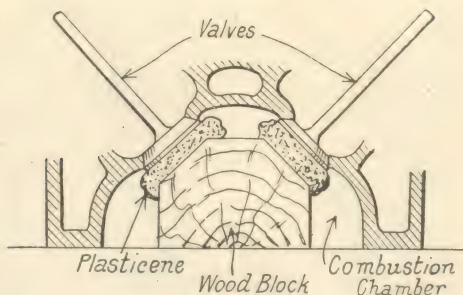


FIG. 28. PREVENTING BENDING OF INCLINED VALVES

the machined face is on the bench. Then, with a cut-away tubular tool similar to that shown in Fig. 27, compress the valve springs in turn and remove the cotters or split collars. The valve springs, collars and the valves themselves can readily be removed. The tool shown in Fig. 27 can readily be made by mounting a piece of $\frac{5}{8}$ in. or $\frac{3}{4}$ in. by 16 s.w.g. mild steel tube in a suitable handle.

In the case of *engines having inclined overhead valves*, as there is a risk of bending the valve stems if a plain wooden block is used, it is a good plan roughly to shape the upper part of the block to the combustion chamber form and then to stick a quantity of plasticine moulding clay on top. On this place a piece of paper to prevent the clay from adhering to the valve heads. Upon pressing this device firmly into the combustion space (Fig. 28) it will take up the correct shape and will prove adequate to prevent the valves from opening when their springs are compressed for removal purposes.

Cleaning Valve Heads. In many cases the carbonaceous matter on the valve heads and tops of the valve stems,

under the heads, can be removed by wire brushing, but in instances where a large number of valves has to be cleaned a good method, due to S. D. Heron of the Ethyl Gasoline Corporation, is the electrolytic one, which is both

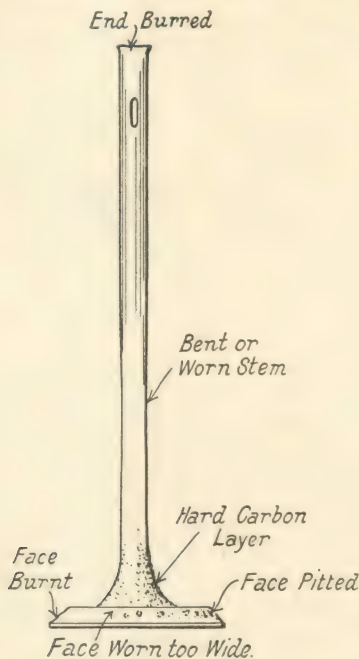


FIG. 29. TYPICAL VALVE DEFECTS

quick and very effective. It consists in melting a mixture of sodium hydroxide, three parts, and anhydrous sodium carbonate, two parts (by weight), in a suitable vessel and immersing the valve head in the molten mixture. The valve is connected to the negative pole of a direct current supply, another immersed metal anode being used as the positive pole connection. The salt is kept at a temperature of 800° to 900° F. and a current of $\frac{1}{2}$ -ampere is passed through the mixture for about ten minutes. An ordinary car battery can be used as the source of current. The valve is then

removed and the deposit can readily be brushed off. Care must be exercised in connection with the molten caustic; it is advisable to wear gloves and goggles.

Valve Life with Leaded Fuels. Some Precautions. It is well known that when fuels containing tetraethyl lead are used in automobile engines the exhaust valve faces and the areas under the head tend to become eroded or pitted, whilst the valve stem tends to "gum-up" in its guide after

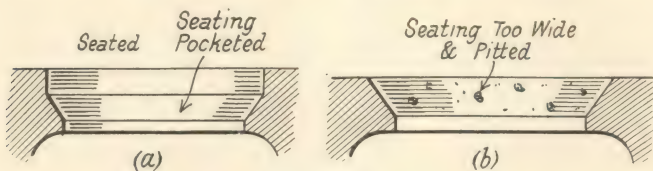


FIG. 30. TYPICAL VALVE SEATING DEFECTS

lower mileages than with non-leaded petrols. Without going into the causes of these troubles it can be stated that to reduce or obviate the effects the valve should run as cool as possible. The valve clearances require more frequent checking than when ordinary petrol is used as a fuel. The valve face and its seating should be rather wider than usual in order to allow the seating to conduct the heat away more freely from the exhaust valve. The use of over rich or too weak mixtures should be avoided and the ignition advance should be carefully checked, so that the engine runs with as much advance as possible, without knocking under load. The valves should be reground at shorter intervals than when ordinary petrols are used and the valve stems kept polished. The valves when reground or refaced should have a fine polished surface so as to give the best degree of contact with the seatings.

Examination of Valves and Seatings. The valves, after removal, should be cleaned with paraffin and the springs, collars, and cotters placed in a jar containing paraffin.

The cleaned valves should then be examined on their seating faces for pitting, burnt-away portions, and ridges (Fig. 30); and the valve stems for excessive wear (Fig. 29). Next, the valves should either be held by their stems in a lathe

self-centring chuck or placed in two Vee-blocks (Fig. 31) and tested with a scribing block or dial gauge for straightness. If found to be bent, they can often be straightened with a hand press, or by judicious tapping on a lead or wood block with a copper hammer; care must be exercised not to injure the surfaces of the valve.

Any valves having seriously burnt seating faces or worn stems should be replaced by new ones of similar pattern.

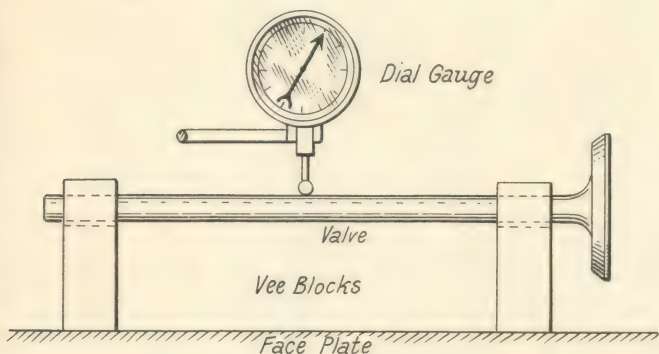


FIG. 31. TESTING FOR BENT VALVE STEM

Reconditioning the Valves. Valves which have ridged or pitted seating faces may be reconditioned by one of the following methods—

(1) By grinding the valve face on to the cylinder valve seating with a fine abrasive. This method is used when the face is only slightly pitted or scored.

(2) By skimming off the valve face in a lathe. If properly carried out, an excellent job can be made of the valve face, but care is necessary to ensure the correct face angle.

(3) By grinding the valve in a special valve facing machine of the type shown in Fig. 32. In this garage pattern machine the valve is held at the correct angle in a collet chuck and rotated slowly by an electric motor while a grinding wheel driven by the same motor is brought into contact with the face of the valve so that it grinds away the defective portions.

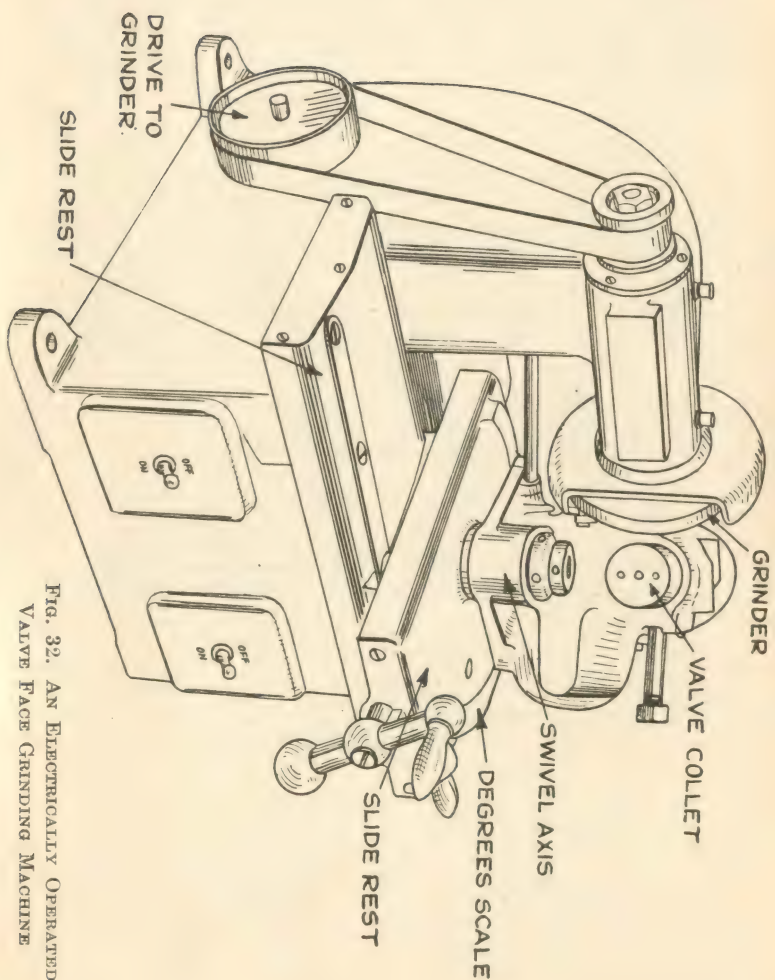


FIG. 32. AN ELECTRICALLY OPERATED
VALVE FACE GRINDING MACHINE

(4) By means of a serrated or plain cutter valve facing tool, such as the J.S. (Fig. 33) or K.B. (Fig. 34) tools.

After a valve has been refaced by methods (2), (3), and (4) it should be ground on to its seating in the cylinder or head to ensure proper bedding down. The grinding machine method (3) gives a better finish than that obtained with the tools or cutters of (2) and (4).

Reclaiming Worn Valves.

Whilst in many instances it is cheaper to replace a worn valve with a new one, cases frequently occur where the valve can be given a new lease of life by building up the worn surfaces, namely, the valve face and stem end by welding. This method is used in some servicing departments dealing with a large number of vehicle engines.

The materials used for building up the worn surfaces are (1) $3\frac{1}{2}$ per cent nickel steel rod of about $\frac{1}{8}$ in. diameter, (2) Nickel-chrome alloy rod of $\frac{1}{8}$ in. diameter, and (3) a special alloy of nickel, chrome, cobalt and tungsten having a high hardness value.

The material (1) is welded on to the worn areas, using an oxy-acetylene flame and a non-injector type of blowpipe having a nozzle giving a consumption of about 4 cu. ft. per hour, i.e. about 100 litres. It is advisable, where quantities of valves of a similar pattern are to be treated, to rig up a vertical position welding jig; this should hold the valve with its head downwards and stem vertically above.

The valve surfaces to be deposited upon should be scraped, ground, or filed to remove all traces of carbon deposit.

When $3\frac{1}{2}$ per cent nickel steel rod is to be deposited a neutral flame must be used; the valve should be warmed up, i.e. preheated, before depositing the nickel. If the valve

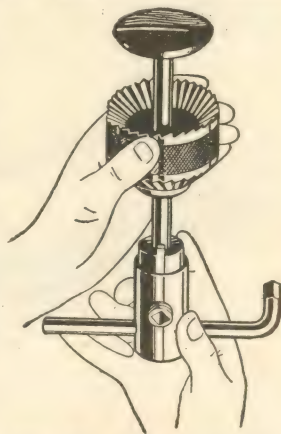


FIG. 33. THE J.S. VALVE FACING TOOL

is badly worn it should be built up in two runs, the surface of the first run being ground before the second run is made. After deposition the valve should be heated as a whole and allowed to cool very slowly. The alloys (2) and (3) are deposited by the "surface fusion" method. A similar blowpipe tip to that recommended for the $3\frac{1}{2}$ per cent nickel steel and the flame adjusted to neutral with a cone

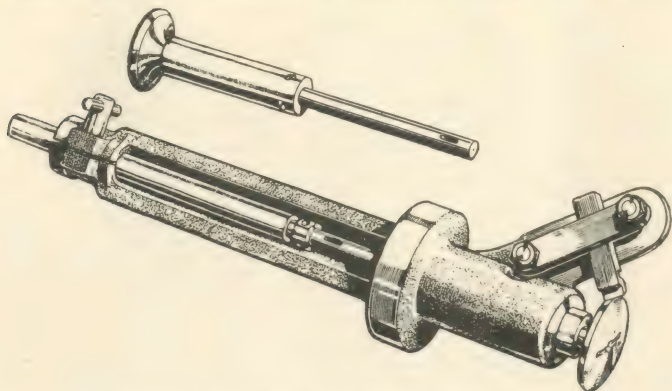


FIG. 34. THE K.B. VALVE FACING TOOL

of normal length (Fig. 35)*. A carbonizing flame is then obtained by turning down the oxygen supply until the white cone of excess acetylene is $1\frac{1}{2}$ to $2\frac{1}{2}$ times the length of the inner cone. After preheating the valve the flame is applied to the seating face with the inner cone just above the surface of the steel. At the same time the welding rod should be held in the flame to warm it up. When the surface of the valve begins to "sweat" and form a film of carbonaceous steel the end of the rod should be brought under the flame, and the small bead melted off will then spread over the surface of the steel and "tin" it. The rod is then fed on to this surface until the desired thickness is obtained, making one or two runs as required. The flame is then withdrawn slowly. To render the subsequent grinding operation easier the deposit can be remelted and the valve

**Reclamation of Worn Petrol Engine Valves.* Ministry of Supply.

rotated slowly so as to give a fairly smooth surface free from ripples. The valve should then be cooled very slowly by covering it with silver sand or lime (powdered).

In regard to the three materials recommended the first is the softest and the latter the hardest. The last material requires a special type of grinding wheel.

It may be mentioned that worn parts such as tappets,

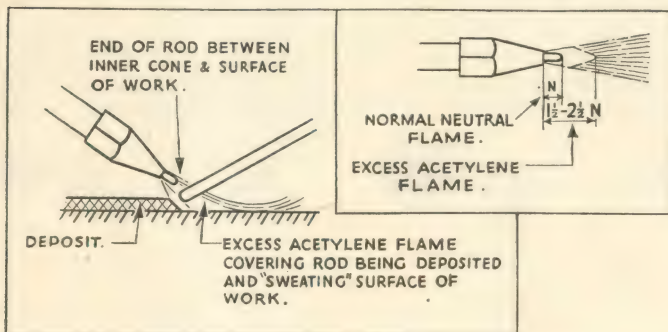


FIG. 35. SHOWING (above) TYPE OF WELDING FLAME USED IN DEPOSITING METAL ON VALVES, ETC.
(left) METHOD OF USING BLOWPIPE AND ANGLE OF NOZZLE TO WORK

rockers, clutch fingers and certain other engine components can be built up in this manner.

Stelliting Valve Faces and Stem Ends. The maximum service can be obtained from valves if their faces and stem ends are given a deposit of stellite. The latter is an extremely hard alloy of chrome, cobalt and tungsten and is much used as a cutting material for the tips of high performance machine tools. It can be obtained in the form of rod of $\frac{3}{16}$ in. diameter and may be drawn out to a smaller diameter, if required, by heat application.

The exhaust valves of aircraft engines are invariably treated with stellite or another very hard nickel-chrome alloy, known as Brightray; many commercial vehicle petrol and Diesel engine valves are also stellited. Stellite can be deposited from the rod with an oxy-acetylene flame after the surface of the valve has been properly cleaned to give

a high finish, free from cracks or pits. In instances of bad pitting the surface should first be built up with $3\frac{1}{2}$ per cent nickel steel rod in the manner described previously.

For stelliting with a high pressure welding outfit the gauge pressure for both oxygen and acetylene supplies should be between 2 and 4 lb. per sq. in. The blowpipe flame should be adjusted until the small inner cone is about $\frac{3}{16}$ in. to $\frac{1}{4}$ in. long and the larger white cone, about $\frac{3}{4}$ -in. long, corresponding to an excess of acetylene; it is important to maintain this excess-acetylene flame and to use the smallest size of blowpipe which will deposit the stellite satisfactorily. The valve should be preheated before



FIG. 36. METHODS OF STELLITING VALVES

depositing the alloy and, in general, the same methods are used as in the preceding example for welding other alloys on to valve surfaces. As stellite is too hard for the use of ordinary grinding wheels it is necessary—as also when re-truing stellited valves—to employ a special grade of grinding wheel, e.g. carborundum 50 K.E. 4. The thickness of the deposited stellite when the face is ground to size is $\frac{1}{32}$ to $\frac{3}{64}$ in.; the thickness on the end face of the valve stem should be $\frac{3}{64}$ to $\frac{5}{64}$ in. Fig. 36 (A) shows the usual method of stelliting a valve face and (B) an alternative method, where the valve face is first ground concave before the alloy is fused on.

Grinding Valves on their Seatings. This method consists in smearing lightly the valve face with a paste made by mixing fine carborundum or emery powder with petroleum jelly, or with one of the proprietary valve-grinding compounds on the market. The valve is then inserted on to its correct seating and turned to and fro, using a screwdriver or special valve grinding tool for the purpose. At intervals the

valve is lifted off its seating and then returned for a few more grinding movements. The valve should not be rotated continuously or scores may result. It is a good plan, when several valves have to be reground on to their seatings to make a screwdriver-ended tool from a piece of $\frac{3}{8}$ in. round mild steel rod, by hammering the red-hot end flat. This

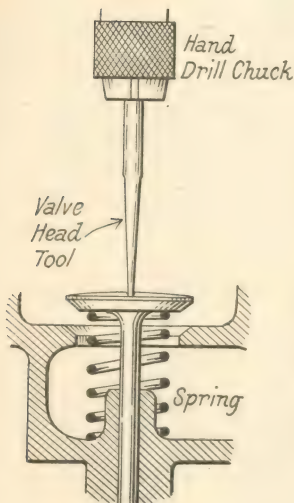


FIG. 37. THE VALVE GRINDING OPERATION

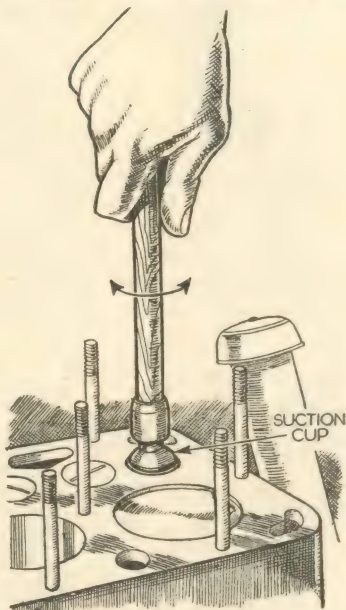


FIG. 38. SUCTION-TYPE VALVE HOLDER

tool can then be used in the chuck of a hand drill and reciprocated—for the chuck will hold it firmly enough for this purpose. A light spring should be placed under the valve head in order to lift the valve when pressure is removed (Fig. 37). In this way pitted valves or seatings can quickly and efficiently be reconditioned.

After each period of grinding, remove the valve and wipe its face and valve seating with a paraffin-moistened rag for examination of the faces. When these are bright and

free from scores or pittings, give them a thorough cleaning with paraffin, taking care to remove all traces of abrasive from the cylinder seatings and valve ports.



FIG. 39. TOOL FOR GRINDING OVERHEAD VALVES

Valves which do not have slotted heads may be reground with the aid of the suction cup type tool shown in Fig. 38. This can either be used by hand or in the chuck of a hand drill.

Overhead pattern valves may be reground, either by the method described or with stem-holding tools such as the Terry one shown in Fig. 39. The Armstrong-Siddeley tool for holding overhead valves by their stems and the method of operating the device are illustrated in Fig. 40.

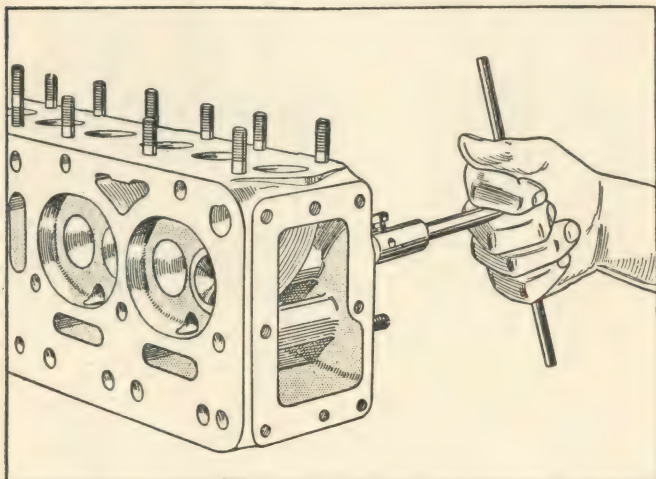


FIG. 40. REGRINDING OVERHEAD VALVE (ARMSTRONG-SIDDELEY)

The tool has a drilled head to fit over the valve stem, the head being locked to the valve with the set screw shown.

The Valve Seatings. Before grinding the valves on to

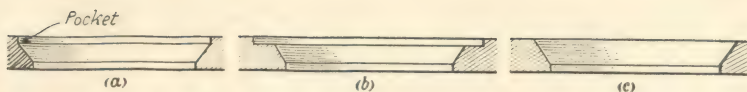


FIG. 41. METHODS OF RECONDITIONING VALVE SEATINGS

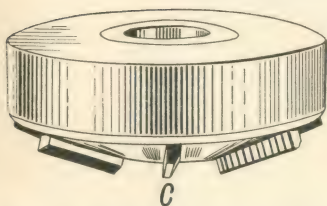
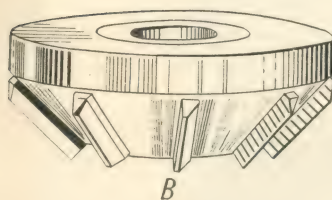
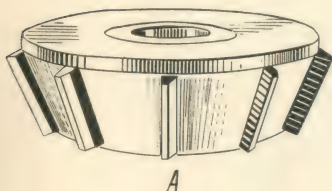


FIG. 42. VALVE-SEATING CUTTERS
FOR RECONDITIONING WIDE
SEATINGS

A = 15° *B* = 45° *C* = 75°

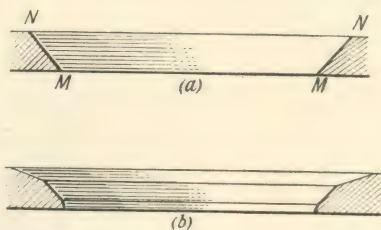


FIG. 43. RECONDITIONING VALVE
SEATING

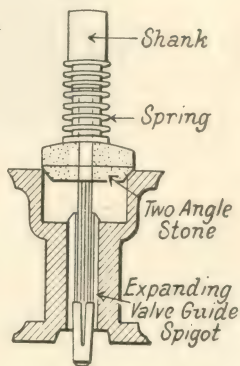


FIG. 44. TOOL FOR HARD
VALVE SEATINGS

their seatings, the latter should be examined carefully for pocketing or excessively wide faces.

The cure for a pocketed seating—which is a source of inefficiency in engine performance—is to remove the surplus metal with a flat or conical milling cutter used in a hand-operated or portable electric tool.

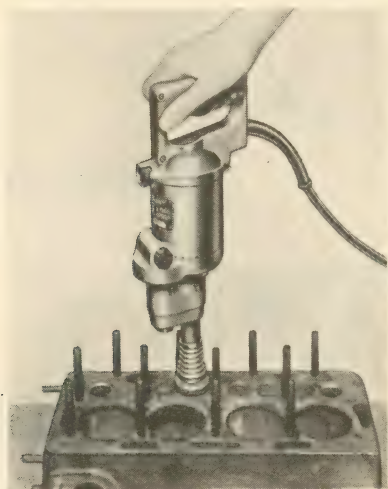


FIG. 45. GRINDING VALVE SEATING

Fig. 41 (*a*) illustrates a valve pocket, while Fig. 41 (*b*) shows how the surplus metal is removed with a flat cutter, and Fig. 41 (*c*) the method of cutting it away with a conical cutter.

When using valve reseating tools it is necessary to use a pilot rod which is a good bearing fit in the valve guide, in order to ensure concentricity of the new seating with the valve guide hole.

Wide valve seatings are usually dealt with by means of two conical milling cutters (Fig. 42), one of 15° angle to remove the metal shown at *M* in Fig. 43 (*a*) and the other of 75° angle to cut away the metal at *N* in Fig. 43(*a*); the result is to reduce the width and to give a kind of

stream-line flow shape to the cut-away portions, as shown in Fig. 43 (b).

Grinder for Valve Seatings. A quick and efficient method of truing up worn valve seatings is to employ a special type of grinder having the same conical angle as that of the valve seating and a pilot member which is a running

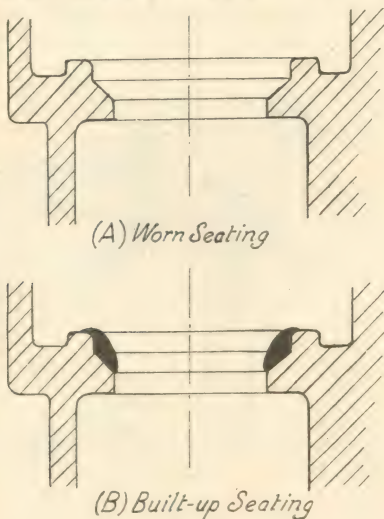


FIG. 46

fit in the valve guide, to ensure that the ground seating is concentric with the valve guide (Fig. 44). The tool is used in a portable electric machine as illustrated in Fig. 45.

Building Up Worn Valve Seatings. When the valve seating becomes so worn that the valve head works in a pocket, it is possible to build up the seating by the oxy-acetylene welding method, so that the original form of the seating can be obtained (Fig. 46). Alloy cast iron welding rods giving deposited metal of excellent wearing qualities, with suitable fluxes, are employed. The cylinder blocks should be preheated before and annealed after welding. The deposited metal is then machined with a suitable valve cutter of the usual milling cutter tooth form, and finished

off by grinding with the aid of a suitable shape of stone. The valve guide is utilized for the pilot portion of the cutter and grinding stone to ensure accurate concentricity of the new seating.

Hardened and Stellite Valve Seatings. These seatings cannot be reconditioned by the methods previously given since they are too hard for ordinary cutters to deal with.

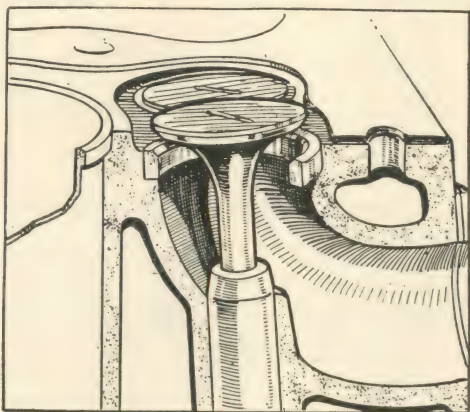


FIG. 47. VALVE SEATING INSERT (MORRIS)

It is necessary, therefore, to employ conical abrasive stones of a special kind made for this purpose, the stones being used with a portable electric drilling machine tool.

Fig. 44 shows a suitable tool of this kind, having a self-centring pilot member engaging with the hole in the valve guide. There is a spring between the stone and the chuck above to give a variable pressure when grinding the seating.

Valve faces are usually at 45° , but in the case of certain engines (including motor Diesel ones) the faces are sometimes at 30° .

Valve Seating Insert Rings. In the majority of engines the cast iron used for the cylinder block is of such a composition that while it possesses fluidity and sharp moulding qualities it is not so hard as some of the other grades of cast iron, such as the white irons (which do not cast well into intricate cored shapes). In consequence parts such

as valve seatings and cylinder walls do not give satisfactory wearing qualities over moderately long running periods.

It is therefore becoming the custom when reconditioning engines having cylinders of this grade of iron to employ valve seating inserts made from nickel chromium and other alloy steels, or rings having their valve seating faces treated with extremely hard cobalt-tungsten carbide alloys such as stellite.

In regard to the *wear-resisting properties* of various metals and alloys used for valve seating insert rings, the

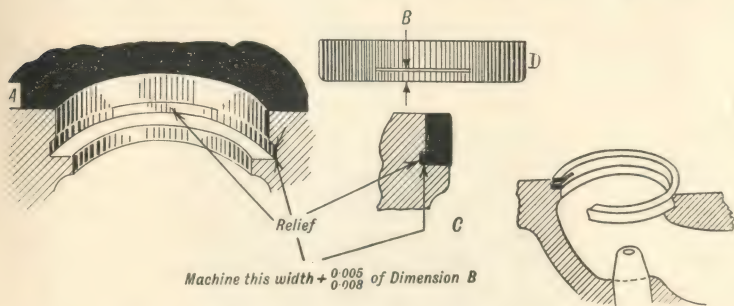


FIG. 48. THE WELLWORTHY INSERT VALVE RING

results of a lengthy series of tests made by the Institution of Automobile Engineers indicate that heat-treated high tensile steel with a stellite facing, used in conjunction with a stellited face silchrome exhaust valve gave the greatest resistance to wear. Other materials giving long service include monel metal, chrome-molybdenum cast iron, beryllium bronze and 30 per cent chromium cast iron. Brightray has very similar wear-resistance properties to stellite, although it is, relatively, much softer.

When the valve faces are given a deposit of stellite or brightray, the length of service before regrinding of the exhaust valve becomes necessary is from four to six times that of an ordinary alloy steel (heat and corrosion resisting grade) valve. Moreover, the alloys mentioned offer a very high resistance to the corrosive and erosive effects of petrols containing tetraethyl lead, i.e. leaded fuels.

Owing to the hardness of stellite deposits special grinding wheels* are required for truing them.

These rings are inserted and held in various ways. Sometimes they are made a shrinkage fit in the cylinder

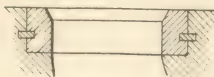


FIG. 49

recesses while in other cases they have special keying rings or projections to prevent their displacement owing to heat and valve hammering action.

In the shrinkage fit method the external diameter of the insert ring is made about 0.002 to 0.003 in. greater than that

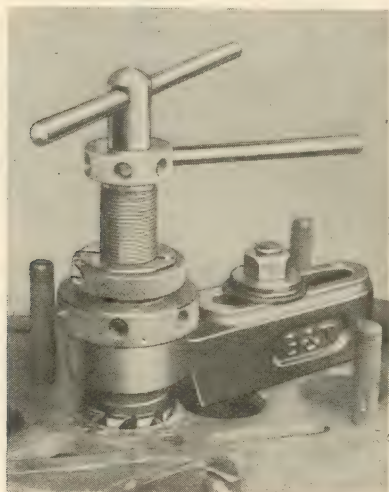


FIG. 50. THE BONEHAM AND TURNER INSERT RING TOOL

of the cylinder insert ring hole. Fig. 48 shows the Well-worthy insert ring method. The cylinder seating *A* is bored out with a plane portion and relief or recess. The insert ring *D* has a slit cut on two opposite sides, such

* Made by the Carborundum Co. Ltd., Manchester.

that when the ring is pressed into the cylinder seating the part of the ring below the slit springs out into the recess as at *C*. Fig. 49 shows another valve insert ring with a spring

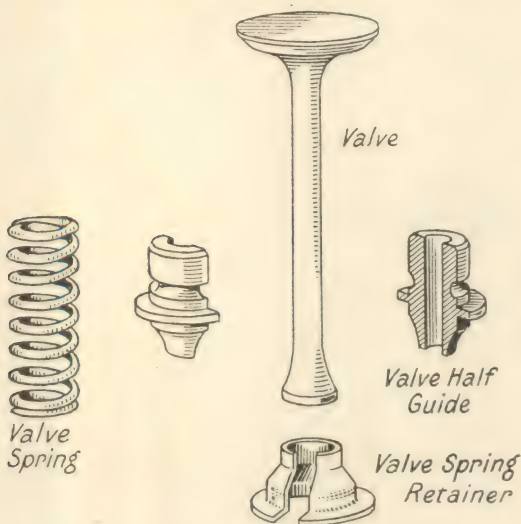


FIG. 51. THE FORD VALVE AND ITS COMPONENTS

ring—resembling a piston ring engaging with a recess cut in the cylinder seating.

In other instances the rings are made a press fit in their holes.

It should be mentioned that valve seating inserts are sometimes inserted into their housings by a *freezing contraction method*, similar to that employed for cylinder liners. In the case of an insert ring of 2 in. diameter, if this is immersed in liquid oxygen at minus 180° C. the shrinkage on the diameter will be 0.0045 in. as compared with the normal air temperature of 20° C. If the cylinder block be warmed a still greater difference in the diameters of the housing and insert ring is obtained.

Special valve seat boring tools, such as the Boneham & Turner (shown in Fig. 50) and the Buma are now available.

The former tool not only cuts the correct size and depth of hole in the cylinder block, but also embodies a screw press for forcing the insert ring into the hole that has been bored; further, it will then face the seating to the correct angle to suit the valve face.

The Ford Engine Valves. The valves used in Ford engines differ from the usual pattern in having an expanded portion at the tappet end as shown in Fig. 51; this affords a bigger area to resist impact wear, since the valve tappets are not adjustable for clearance. It will be evident

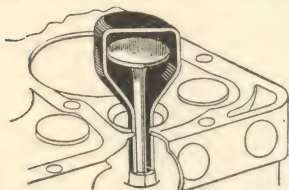


FIG. 52. THE ZIM TOOL

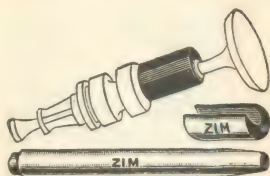


FIG. 53

that with these valves the usual valve guides cannot be employed since the expanded ends will not pass through the guides. The latter are therefore made in split form, i.e. in two similar halves which are inserted from below after the valve stem is passed through the guide hole; they are held in position by means of the valve spring. In order to remove this type of valve the spring is first compressed with a tool of the type shown in Fig. 21D and the slotted coned keeper slipped out sideways. The valve can then be pushed up and the main collar and spring taken off. Next, with the valve in the lifted position a copper drift is used to drive the two halves of the valve guide downwards; the drift is inserted between the lifted valve face and the valve seating. A special tool, known as the "Zim"* (Fig. 52), is now available for removing the split guides. It consists of a steel pressing of half-section, inserted from the side under the lifted valve; the tool is tapped or pushed downwards to force out the guides.

In the case of tight Ford valve guides another "Zim" tool (Fig. 53) should be used. It consists of a hardened slotted

* Messrs. E. P. Barrus Ltd., London, W.3.

rod member which is slipped sideways over the lifted valve stem, above the guide, and a brass drift to use when hammering the slotted rod, the lower end of which is in contact with the tops of the guide.

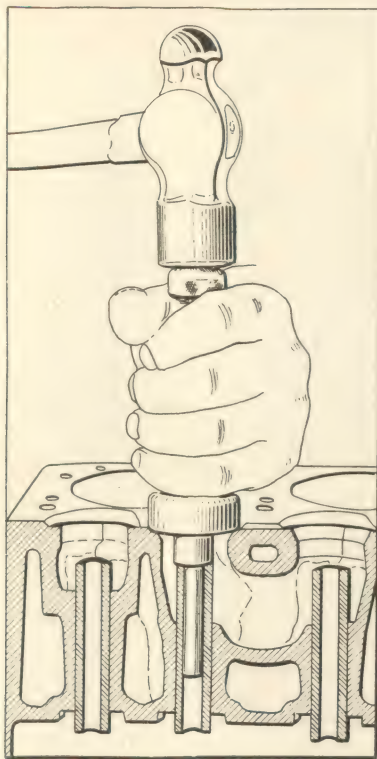


FIG. 54. REMOVING THE VALVE
GUIDE

It should be mentioned that the later model Ford Vee-Eight valve guides are held in place by cotter plates in the cylinder block just above the tops of the springs—which hold them in position. Upon releasing the spring pressure with a suitable lever, the cotter plates can be pulled out

and the complete valve assembly, namely, the valve, spring guide, and collar, removed bodily from above.

Removal of Ordinary Guides. When it is necessary to remove the ordinary type of valve guide this can either be punched down from above (Fig. 54) or extracted with a screw device as shown in Fig. 55.

Replacing the Valves. Usually, it is more difficult to replace the valve springs and collars and to insert the

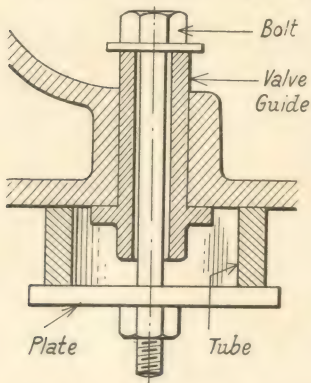


FIG. 55. REMOVAL OF VALVE GUIDE AND SCREW PRESS

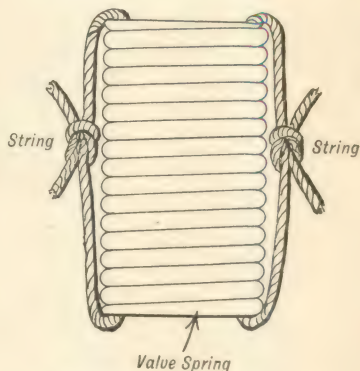


FIG. 56. HOLDING SPRING COMPRESSED

cotters or split collars than to remove them. In most designs the same tool can be used for compressing the spring (with its collar) as for removing it; the tool, in such cases, must be of the self-locking type.

In instances where such tools are not available or convenient to use, the valve springs can be compressed in a vice and tied up in two opposite positions with pieces of strong string (Fig. 56). After inserting the spring and its collar, the cotter or similar device is placed in position in the valve stem groove or hole and then the string is cut with a sharp knife and the pieces of string pulled away with a pair of flat-nose pliers.

Sometimes the spring can be compressed in the vice or with a screw and nut device and a sheet metal holder or pair of holders employed to retain it in its compressed

condition for insertion. Two pieces of cycle spoke each bent at the ends to form two right-angles (Fig. 57) and tied in place with string will also be found useful for this purpose.

Resetting the Valve Clearances. After replacing the valves the clearances between the valve stems and the rocker arm ends or tappets should be adjusted to the values recommended by the manufacturers of the particular engine.

Usually, for side-valve engines the inlet and exhaust

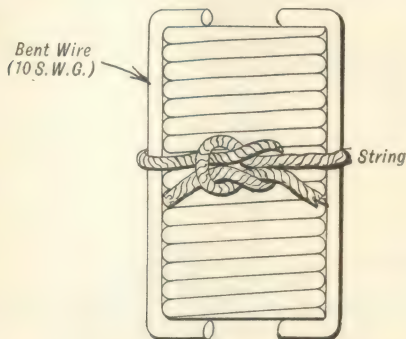


FIG. 57. ALTERNATIVE METHOD OF HOLDING SPRING IN COMPRESSED CONDITION

valve clearances are set at 3- and 5-thousandths inch respectively. For push-rod and rocker arm type overhead valves the clearances are 4- and 6-thousandths inch respectively, with the engine hot. For overhead camshaft engines, clearances, for both valves, of 3- to 4-thousandths inch are generally used.

Several designs of modern engines, notably the Morris, Standard, Wolseley, and Lanchester, employ special cam shapes which enable larger clearances to be employed, thus obviating the necessity of frequent clearance checking. With the Morris engine (Fig. 60) a clearance of about 19-thousandths inch is recommended, with the engine hot, and 20-thousandths inch with it cold. To adjust the valve clearance a feeler gauge of the correct thickness should be inserted between the valve stem end and rocker arm (or tappet) and the rocker arm adjusting screw (or tappet

adjustment) turned until the gauge is held in such a manner that it can just be pulled out without effort (Fig. 58). The adjusting screw or tappet locking device should then be locked securely. Afterwards check the clearance again to

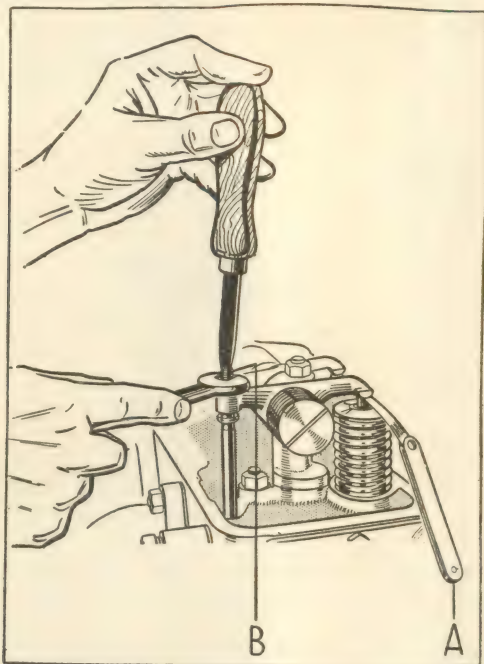


FIG. 58. ADJUSTING OVERHEAD VALVE CLEARANCES
(ARMSTRONG-SIDDELEY)

A = Feeler gauge B = Adjusting screw in rocker arm

ensure that the act of locking the adjustment has not affected it. With side valve tappets a pair of thin spanners is used to unlock the adjusting screw and to lock it again after adjustment has been made (Fig. 59).

It is important to recheck the valve clearances after the engine has run about 100 to 200 miles, since valves that have been reground are liable to bed down slightly on their seatings.

No attempt should be made to employ smaller valve clearances than those recommended by the makers; otherwise burnt valves will probably be the result.

Adjusting Austin Hydraulic Overhead Valves. The more recent larger model Austin cars, notably the 16 h.p. four-cylinder overhead valve engine one, are fitted with an hydraulic device which maintains the push-rod, rocker arm and valve stem in close contact so that the operation

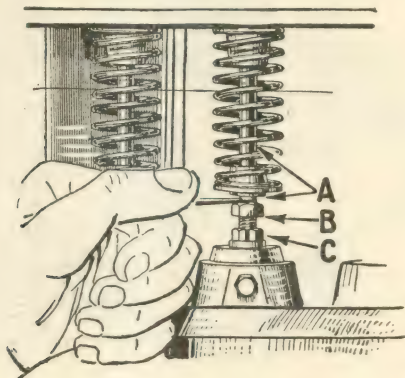


FIG. 59. ADJUSTING SIDE VALVE CLEARANCES (AUSTIN 10)

A = Valve stem B = Tappet screw C = Lock-nut

is very quiet. The top portion of each push rod is a sliding fit in the lower half and oil under pressure is fed from the lubrication system through drillings in the rocker arm and top portion of the push rod. The result is that when the valve is closed there is no clearance between the end of the valve stem and valve rocker. As the push rod rises to open the valve the oil cushion is squeezed out but builds up again as soon as the valve closes.

When checking or adjusting the valve clearance between the rocker arm and valve stem *the rocker arm must be pushed down hard on to the push rod* to disperse the oil cushion, so that the true clearance can be checked or set with a feeler gauge.

The correct clearance between the valve stem end and rocker arm is 0.012 in.

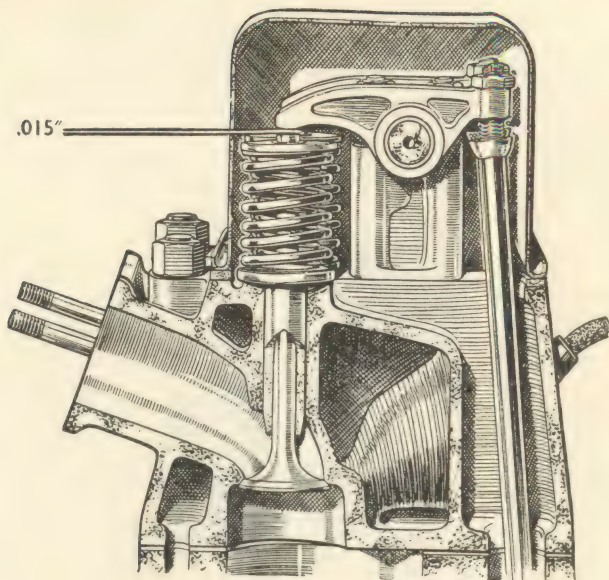


FIG. 60. THE MORRIS OVERHEAD VALVE

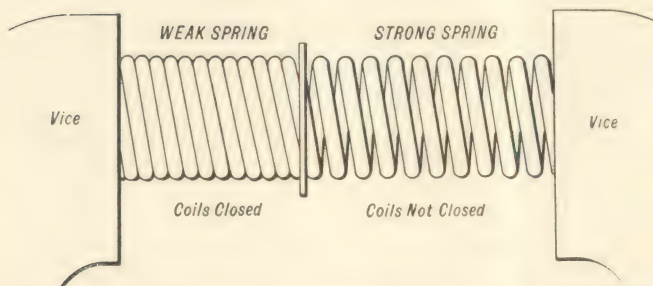


FIG. 61. METHOD OF TESTING VALVE SPRINGS

Sticking Valves. These are caused by oil leaking down the stems and becoming burnt, thus forming a hard or gummy deposit. Uneven running or blow-back in the carburettor is an indication of this. When valve sticking occurs it may be cured by squirting a little upper cylinder lubricant, mixed with petrol, on the stems; paraffin may also be used to free the valve stems.

Weak or Broken Springs. Weak valve springs result in a loss of engine revolutions and therefore of maximum power output. Broken springs, which can usually be detected by inspection or by noisy operation, have a similar effect. When an engine has been in service for a long period and is then dismantled for overhaul, each of its valve springs should be tested for comparison by placing it against a new spring and testing the two for relative compression in a vice (Fig. 61). The weaker spring will compress to a greater extent, as shown: it should accordingly be replaced by a new spring.

CHAPTER V

THE PISTON AND PISTON RINGS

Removal of the Gudgeon Pin. The piston, having been removed together with its connecting-rod, from the engine, the former should first be detached, by taking out the gudgeon pin. The latter is usually fitted into the piston bosses as a light push fit, the pin being secured against end movement in

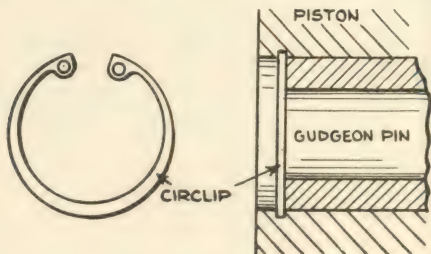


FIG. 62. LOCKING GUDGEON PIN WITH CIRCLIP

the piston by means of spring clips (Fig. 62) known as "circlips." With the aid of a pair of round-nosed pliers, the two ends of the ring can be pulled towards each other when the ring will become sufficiently free to enable it to be taken out. The gudgeon pin should then be tapped gently out with a copper or hard wood drift.

The piston may be held in the hand for this operation ; it should not be placed on any metal surface or the relatively soft aluminium alloy will become damaged.

Gudgeon pins which are held in place by *the thermal fit method*, whereby the piston metal is first expanded by a boiling water or electric heating device, before the cold pin is pushed into place, can be removed by immersing the head of the piston, up to the level of the bosses, in boiling water in order to expand it, when the pin can be tapped out.

Special gudgeon pin extractors of the screw pressure type

are available for refractory cases. Figs. 63 and 64 show two typical tools of this kind.

When the gudgeon pin is secured to the split small end of the connecting-rod, as in certain Morris engines, it can

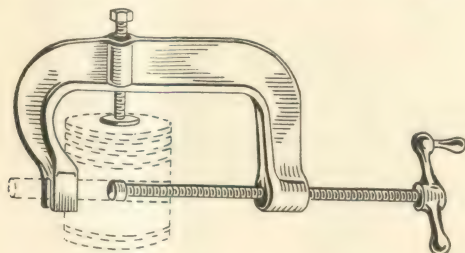


FIG. 63. GUDGEON PIN REMOVAL TOOL

readily be removed after loosening the locking screw with a box spanner, as shown in Fig. 10.

A makeshift device for removing gudgeon pins (Fig. 65) utilizes a bolt, nut, and hard wood block (to avoid damaging the piston) with washer on the clamping face. As the nut

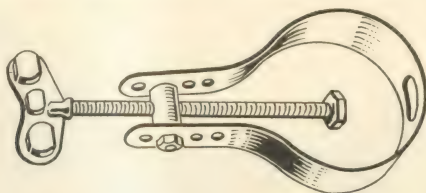


FIG. 64. ANOTHER GUDGEON PIN TOOL

is tightened, progressively the pin is forced out of the piston; the head of the bolt should, of course, be slightly smaller than the outer diameter of the gudgeon pin.

Removing the Piston Rings. Special care is necessary when removing the rings to avoid breaking them. A good plan is to use three strips of hard brass or tinned iron of about 18 to 20 s.w.g. by $\frac{3}{16}$ in. to $\frac{1}{4}$ in. width. Each strip is inserted down near the split part of the ring and is then worked gently round the ring, thus lifting it clear of the

slot. When the three strips have been inserted at equal intervals, the rings can be slid off the piston.

Piston ring removal spring strips can be made from

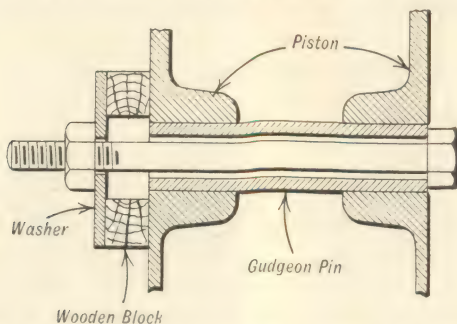


FIG. 65. MAKESHIFT METHOD FOR REMOVING GUDGEON PIN

narrow hacksaw blades with their edges ground so as not to present any sharp edges to the insides of the rings or their slots.

The Wellworthy piston ring removal and installation

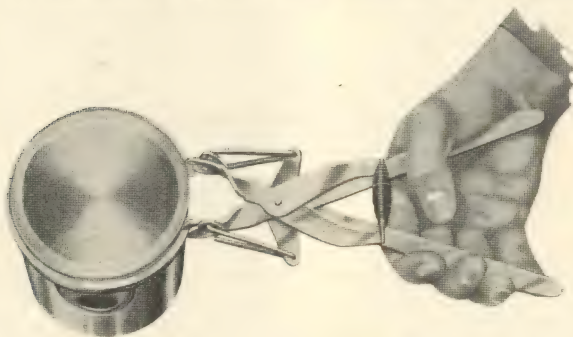


FIG. 66. WELLWORTHY PISTON RING TOOL

tool shown in Fig. 66 is a compact device which actually grips the ring at two places, namely, on either side of the slot and by means of the finger-operated lever shown on the right opens the rings so that they can be slipped out of

their grooves and clear of the piston lands, the operation taking a matter of seconds only.

There are several other designs of piston ring tools available of which it is here necessary to show only one further example, namely, that of the McCarthy, which, as will be seen from Fig. 67, acts upon the same principle as that of a pair of pliers.

The Terry piston ring removal tool (Fig. 68) is provided with a slot through which the ring is prised open for removal. It has also a projection at the end for the purpose of scraping out burnt oil or carbon deposit from the piston ring groove.

Cleaning the Piston. After removal of the rings the piston should be cleaned of any carbon deposit in the piston ring grooves and inside, under the piston crown. A square-end scraper slightly smaller in width than that of the piston ring grooves may be used to dislodge the carbon in the latter, but care is necessary to avoid damaging the aluminium alloy.

The "Zim" groove cleaner shown in Fig. 69 consists of a pair of arms hinged at the right-hand side. The lower arm has a vee-shape to act as a support

for the piston, while the upper arm is provided with a cutter wheel having square-shaped teeth of different widths, any one of which can be locked into the correct position for cleaning the piston ring groove. Another tool operating on a similar principle enables the grooves to be trued to parallelism, a metal cutter being provided for this purpose.

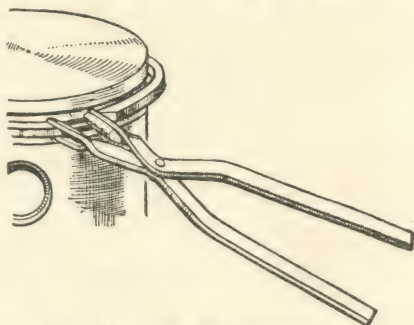


FIG. 67. THE MCCARTHY TOOL

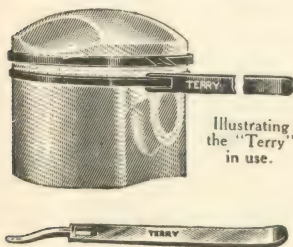


FIG. 68. THE TERRY TOOL

Examination of the Piston. After decarbonizing and cleaning, the piston (Fig. 70) should carefully be examined for the following—

(1) *General Appearance of Working Faces.* If badly

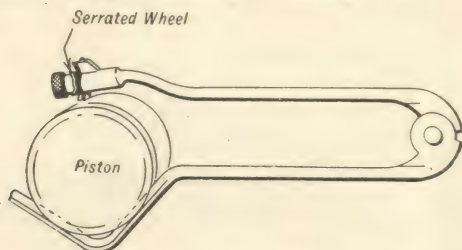


FIG. 69. PISTON RING GROOVE CLEANING TOOL

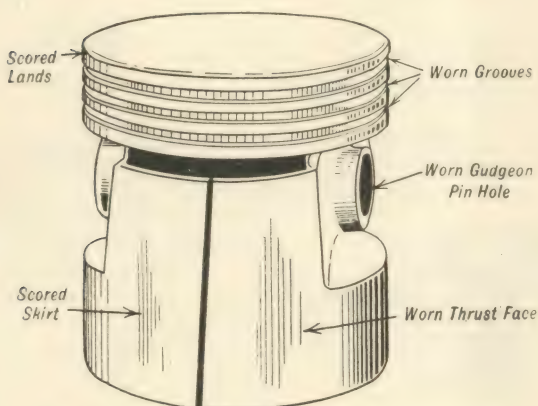


FIG. 70. SOME COMMON PISTON TROUBLES

grooved or scored, the piston should be replaced with a new one.

(2) *Excessive Wear.* Measurements at several places across the thrust face diameters should be compared with those of a new piston or, if this is not available, with those of the cylinder bore, also taken at several places in the barrel. If the clearances exceed the maker's recommended values, the cylinders will require reboring and new pistons fitted.

Usually, most of the wear occurs on the cylinder barrel, due, probably, to the softer piston acting as a kind of lap on the cylinder walls.

(3) *Crown and Skirt.* Examine these very carefully for cracks; if any are found the piston must be discarded.

(4) *The Ring Grooves.* After appreciable periods of wear, the grooves become distorted owing to the hammering action of the harder piston rings as indicated in Fig. 71. When this occurs, and always before new rings are fitted, the metal shown at X, in Fig. 71, should be removed either on the lathe or with the tool mentioned in the previous section; it should never be filed away or the bedding surfaces of the grooves may become damaged and thus cause compression and oil leakages.

(5) *The Gudgeon Pin Holes.* The fit of the gudgeon pin in the piston bosses should be checked. If any slackness or ovality is detected, the bosses should be reamed out until just circular and a new pin fitted; the connecting-rod small-end bush must then be fitted to the larger diameter pin to give the correct bearing fit.

(6) *Scraper Ring Oil Holes.* The oil return holes through the piston walls at the bottom of the oil control ring groove should be cleaned out with a piece of wire, to ensure the free passage of the oil scraped off the walls by the working edge or edges of the ring.

Replacement Pistons for Rebored Cylinders. The service engineer has a choice of several alternative designs of pistons to replace the worn ones, after the cylinders of an engine have been rebored. It is, however, important from the point of view of engine balance to ensure that the total weight of the replacement piston, complete with its piston

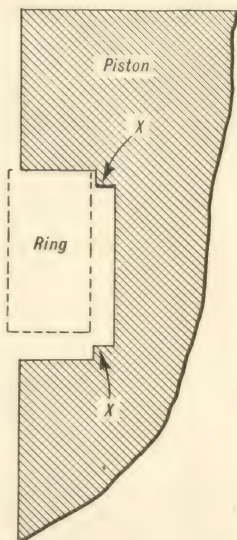


FIG. 71. WORN PISTON
RING GROOVES

rings and gudgeon pin, is the same as the original piston assembly. Replacement pistons can be classified as follows, namely—

- (1) Split skirt types.
- (2) Nickel-iron compensated types.
- (3) Oval ground self-adjusting types.

(1) *Split Skirt Pistons*. In order to prevent piston slap, due to the relatively large clearance necessary owing to the fact that the thermal expansion coefficient is about

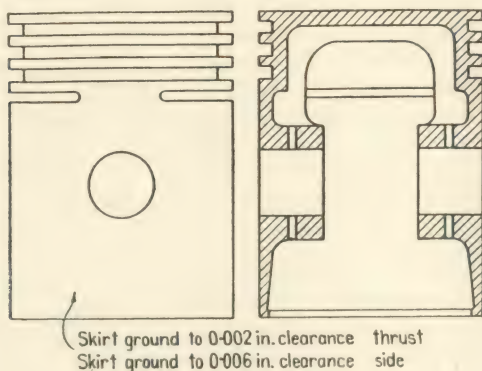


FIG. 72. OVAL GROUND PISTON

$2\frac{1}{2}$ times greater for aluminium than for the cast iron or steel cylinders, the piston skirt is given an outward spring effect by splitting it as shown in Figs. 73 and 74, and arranging for the skirt to make contact with the cylinder walls, instead of having a clearance.

(2) *Nickel-iron Compensated Pistons*. In this type use is made of strips of a non-expanding nickel-iron alloy, known as Invar, cast in position in the aluminium alloy piston. Sometimes plain carbon steel plates are used, the difference between the expansion of the inserted nickel-iron or steel plates and the aluminium being used on the principle of a bimetallic strip to compensate or control the expansion of the aluminium on the thrust faces. It is thus possible to fit this type of piston with a smaller clearance, similar to that of a cast iron piston.

(3) *Oval Ground Pistons*. These pistons are carefully

designed from heat flow considerations and are slightly smaller in the gudgeon pin axis direction than on the thrust face diameter, i.e. at right angles to the gudgeon pin axis (Fig. 72). The head of the piston is usually separated from the skirt portion on the thrust faces of the latter so that the bulk of the heat from the hotter piston crown is conducted through the piston bosses and expands the piston more in the gudgeon pin axis direction than on the thrust face diameter, with the result that when the cold oval-shaped piston warms up it becomes truly circular in section and thus provides a good working fit in the cylinder barrel. The difference between the diameters along and at right angles to the gudgeon pin axis is usually of the order of 0.0025 to 0.006 in. according to the diameters.

The *Wellworthy* "Welfex" piston (Fig. 73) is a typical instance of such a piston and is much used for new and also rebored engines. It is made in the solid and split skirt patterns. The skirt is separated from the piston head and carried upon inner circumferential webs. These inner ribs together with a short length of the outer skirt on the thrust side form a continuous ring of metal nearly up to the actual split. The normal design of piston leaves the split ends unsupported on the whole of the trailing edge, whereas in this piston this area is reduced to the small portion between the ends of the circumferential webs. The presence of the split enables a smaller clearance to be used and prevents seizure should the engine be over-driven during the early stages after a rebore.

This type of piston can be fitted with a minimum clearance of 0.00075 in. for each inch of piston diameter, e.g. a clearance of 0.00225 in. for a 3 in. piston.

There are several other types of new and replacement pistons, of which typical examples are the specialloid "Easy Start" and the Aerolite ones.



FIG. 73. THE WELFEX PISTON

The former type, illustrated in Fig. 74 has a special bracing strut from the crown of the piston to the gudgeon pin bosses, in order to obviate distortion under load.

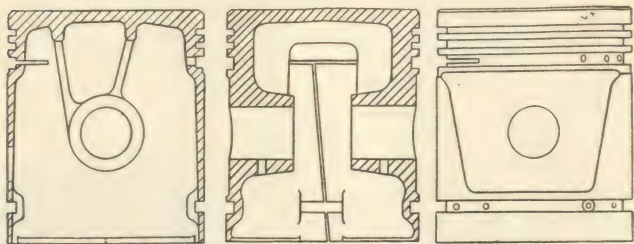


FIG. 74. THE "EASY START" PISTON

Other features include the offset cast relief to give a certain degree of flexibility to the skirt whilst giving ample bearing surface; a split skirt; scraper ring near the bottom of

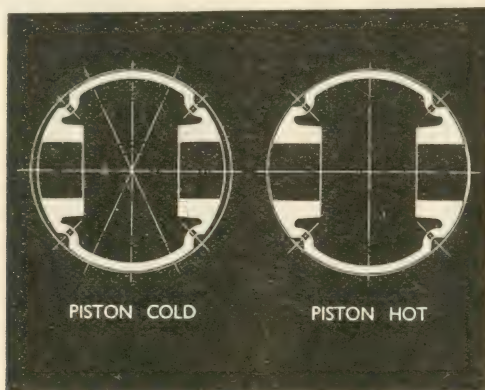


FIG. 75. THE AEROLITE PISTON

the skirt and, finally, the tin coating of the piston bearing surfaces to reduce friction to a minimum.

The Aerolite piston (Fig. 75) is of the oval-ground type shown in Fig. 72. It has four longitudinal grooves which divide it into two thrust and two gudgeon pin faces. A

series of holes is provided in each groove to reduce heat conduction between these sections. A smaller cold clearance can be given and this clearance is maintained almost constant over the whole temperature range.

Examples of a plain and split piston, with typical diameters and land dimensions are shown at (A) and (B), respectively, in Fig. 76, for a piston of nominal $3\frac{1}{2}$ in. diameter for a cast iron cylinder.

Holding the Piston. Pistons, whether of cast iron, steel, or aluminium alloy, should not be held in the vice with lead

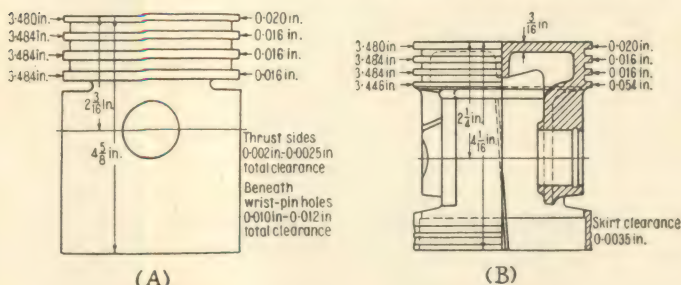


FIG. 76. PLAIN AND SPLIT SKIRT PISTONS

clams, or distortion may easily occur which will render the pistons useless for replacement in their cylinders. A good expedient is to take a square section block of soft wood, e.g. deal or pine, and to bore it out to the piston diameter in the lathe. It should then be sawn through with a wide toothed saw and provided with a leather or thin metal strap as shown in Fig. 77. The divided block can then be used to hold the piston in the vice. Special piston holding vices are sold by garage equipment firms for similar purposes. One typical device for this purpose, known as the G.E. or Bradbury, is that shown in Fig. 78. It is intended to extend over the edge of the bench and has a screw-operated strap for clamping the piston against a cylindrical block-member lined with fabric.

Piston Clearances in Cylinders. The clearance between the piston and cylinder depends upon several factors, viz., as follows:—(1) the material of piston, i.e. whether of cast

iron, steel, or aluminium alloy; (2) the material and bore of the cylinder; and (3) the design of the piston.

For cast iron and steel pistons it is usual to allow about

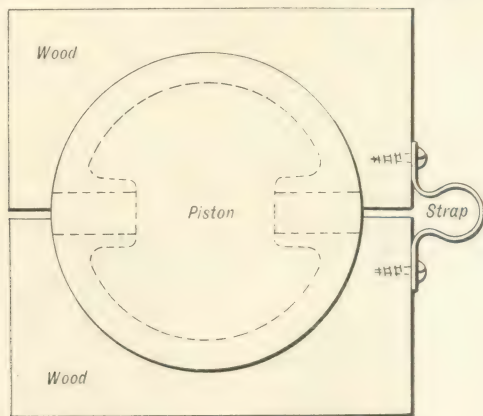


FIG. 77. METHOD OF HOLDING A PISTON

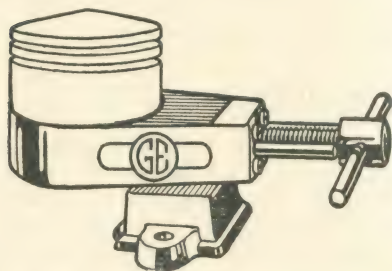


FIG. 78. COMMERCIAL PISTON VICE

0.00075 in. per inch diameter when used in cast iron cylinders, so that a 3 in. diameter piston will have a clearance of about 0.0025 in.

For aluminium, since this metal has a greater expansion coefficient than cast iron, greater clearances must be given. It is usual to allow about 0.0015 in. per inch diameter, so that a 3 in. plain piston will have a clearance of 0.0045 in.

Since the crown of the piston is always much hotter than

the skirt, it is now the practice to give a greater clearance at the top than at the piston skirt; usually the clearances are progressively increased from the skirt to the top piston land.

The following table shows the recommended clearances for aluminium alloy split skirt pistons—

Cylinder bore	in. 2½-3	in. 3-3½	in. 3½-4	in. 4-4½	in. 4½-5
Top land	in. 0.019	in. 0.023	in. 0.028	in. 0.034	in. 0.040
Second land	0.014	0.016	0.019	0.023	0.027
Third land	0.014	0.016	0.019	0.023	0.027
Oil land*	½ in. less than standard cylinder bore				
Skirt	0.002	0.002	0.002	0.003	0.003

With the low expansion alloy pistons, such as the Nelson Bohnalite Invar Strut ones, about the same expansion coefficient as for cast iron is obtained. Thus it is usual to employ clearances of 0.00075 in. per inch of diameter.

Split Skirt Piston Expanders. Split skirt aluminium pistons which have become slightly worn on the skirt portions or have lost their spring effect may be expanded so that the skirt is restored to its original diameter. Whilst it is possible to do this by means of a special peening tool in a similar manner to that used for piston rings, or by means of a screw expander used inside the skirt portion, it requires a good deal of skill and patience in order to ensure that the skirt fits the cylinder bore evenly.

A device known as the Fitzall piston expander can be fitted to any split skirt piston for the purpose of expanding the skirt. It consists of a small and light spring clip of hair-pin form having two projections, namely, one on each spring arm. These are inserted from inside the piston into a ¼ in. diameter hole drilled in the split, in line with the gudgeon pin, using the special tool shown in Fig. 79 for this purpose; alternatively, a pair of pliers may be used. The clip is then securely held in position and cannot

* The land below third piston or scraper ring.

become detached. If more than 0.005 in. expansion is required a wedge is inserted in the split before the hole is drilled; otherwise the expansion will be about 0.005 in. in ordinary practice.

Solid Skirt Pistons. For use in servicing stations where a number of solid skirt pistons require treatment to restore the piston skirts to their original outside diameters, a

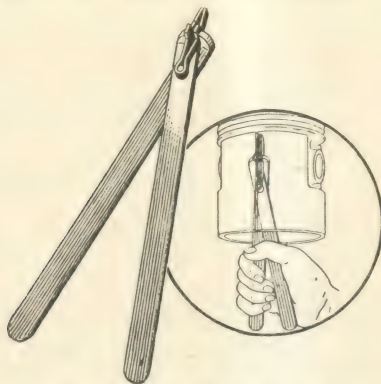


FIG. 79. THE FITZALL SPLIT SKIRT EXPANDER

process known commercially as the "Koetherizer" one can be employed. With this method it is possible to restore the shape and increase the diameter up to 0.005 in. oversize if desired. The method is based on the same principle as that employed for peening piston rings, but instead of using a peening hammer it uses a controlled blast of air and lead shot.

Referring to Fig. 80 which illustrates the principle of the method, a vertical arm on the horizontal bracket holds a jig in the shape of a circle of cast iron on which is placed a pad grooved out to take the piston to be restored. The shot blast is directed through a hole in the jig and pad at an angle to the gudgeon pin boss inside the piston. Whilst this is proceeding the piston is arranged to oscillate over a quarter of a circle and the blast nozzle rises and falls in a semi-circular path in such a way that the expansion of the piston skirt, outwards, is caused mainly on the thrust

face. The air pressure used is about 80 lb. per sq. in. and the process occupies only a few seconds. The method alters the skirt in the required manner and gives the correct degree of ovality and taper.

Hints on Machining Aluminium Alloy Pistons. The diamond tool gives the quickest and best finish. Cutting speeds up to 1500 ft. per min. can be used with such tools. Feeds

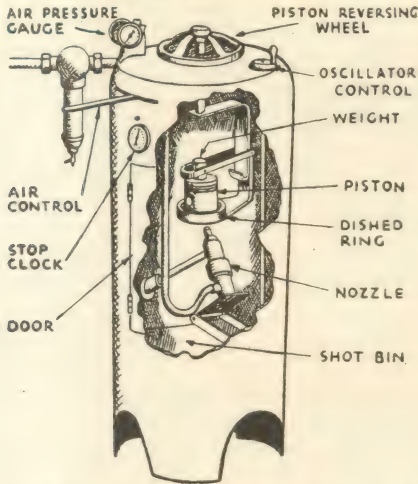


FIG. 80. THE KOETHERIZER METHOD OF PISTON EXPANDING

of 0.001 to 0.003 in. per revolution and cuts of 0.004 to 0.020 are employed. Next, in order of rapid machining are the tungsten carbide-tipped tools which can be employed for cutting speeds of 500 to 800 ft. per min. High speed steel tools are used at cutting speeds of 250 to 400 ft. per min. The top rake of the tool should be 30° ; side rake, 20° ; front clearance, 8° and side clearance, 8° . The cutting edge should be honed or oil-stoned before use. The round-nosed tools give the best finish.

The recommended cutting lubricants are paraffin (kerosene) or turpentine.

Freeing a Seized Piston. If, as a result of lubrication failure or excessive overheating, pistons become seized in

their cylinders, no attempt should be made to force them free. The sparking plugs should be removed and about 4 oz. of methanol or similar antifreeze poured into each cylinder. This will dissolve the hydrocarbon gums without injury either to the pistons or cylinder.

Petrol may be used for the same purpose, but it is not so effective. After the pistons have been eased, a small quantity of lubricating oil should be squirted into each cylinder to ensure adequate lubrication. In an emergency paraffin can be injected into the seized cylinders.

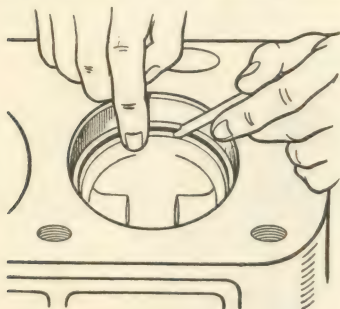


FIG. 81. MEASURING PISTON RING GAP

Piston Rings. When an engine has been used for periods exceeding about 25,000 miles the rings will usually be found to require replacement. The condition of a worn ring may be tested in regard to wear

by placing it in the worn part of the cylinder barrel and measuring the width of the ring gap.

The correct gaps for step cut and diagonal piston rings should be as follows—

Diameter of piston	in. 2	in. 2·5	in. 3	in. 3·5	in. 4	in. 4·5
Ring gap (step cut)	0·003	0·005	0·007	0·009	0·012	0·015
Ring gap (diagonal cut)	0·002	0·003	0·005	0·007	0·009	0·011

The rings should then be tested for side clearance in the piston ring grooves. The correct side clearances should be between 0·001 in. and 0·0015 in.

If the ring gaps, as measured with a feeler gauge (Fig. 81), exceed the recommended gaps by more than about 50 per cent, then new rings should be fitted. Before trying the rings in their piston grooves it is important to remove the carbon from the latter. If the grooves are found to have become stepped (as shown in Fig. 71) or tapered, they should be

trued up, as previously mentioned, and wider piston rings fitted.

Piston rings taken from engines being reconditioned may have the allowable gap and side clearances, and yet not be suitable for use again on account of their loss of "spring"; under these circumstances they do not give sufficient wall pressure to prevent compression leakage.

A piston ring may be tested for "spring" by holding it in contact with a new ring, as shown in Fig. 82. If the two rings are of about the same elasticity, the gaps will both close by the same amount when the two rings are pressed together. If the worn ring is the weaker, its gap will be smaller than that of the new ring.

When replacing piston rings, it is important to fit only the best makes, preferably the car manufacturer's spare ones or a reliable quality of hammered ring, giving uniform radial or wall pressure, unless otherwise recommended.

It is not desirable to use a plain cast iron ring which has

simply to be ground to circular section and then split. If such a ring be fitted into a cylinder, it will be found to touch only at the three places shown in Fig. 83. If, however, the inside of the ring is carefully tapped with a peening hammer, it can be made to assume the circular shape of the cylinder wall, but skill is needed for this operation.

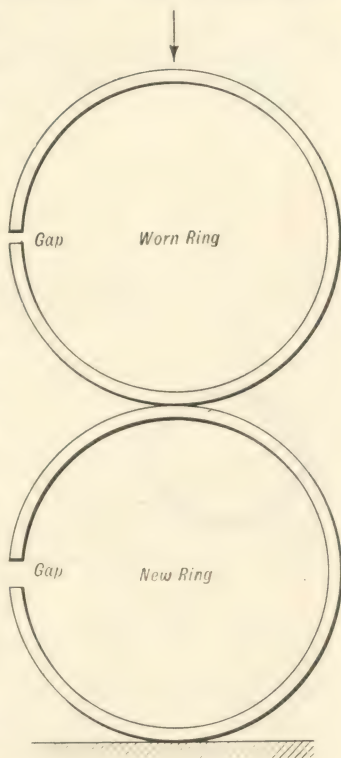


FIG. 82. TEST FOR PISTON RING "SPRING"

Piston rings for replacement purposes may be measured by means of the Bricometer tape device shown in Fig. 84. This is graduated in millimetres from 50 to 150 and shows the diameter (not circumference) when it is placed over a piston ring and then adjusted until the ring gap is closed. The gap portion should be placed towards the bottom of the loop where it can be seen.

Piston rings should be ordered slightly on the large size

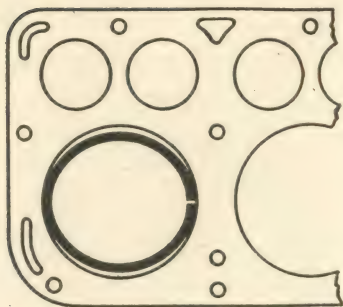


FIG. 83

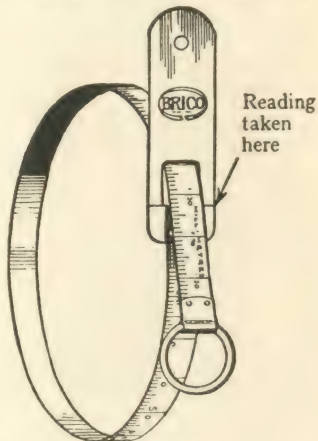


FIG. 84

so that the joint can be filed to ensure a good fit in the cylinder.

Fitting Piston Rings. When fitting new piston rings, it is usual to select them to such a size that when placed in the cylinder barrel *the gaps are too small*. The ends are then ground in a special machine marketed for this purpose, or filed in a special jig, or by hand, until the gap is of the correct width previously indicated.

Fig. 85 illustrates a piston ring grinding machine for use in the larger garages.

Fig. 86 shows a special filing jig for piston ring ends,* having a fine cut file mounted on a flat metal bar, upon which is a vee-shape slider against which the ring is held.

* Messrs. E. P. Barrus, London, W.3.

As the ring and slider are moved up and down the bar the two sides of the ring gap are filed parallel; this device is both quick to operate and accurate.

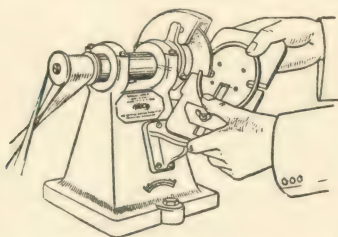


FIG. 85. GRINDING THE PISTON RING ENDS

The file holder is specially slotted to hold the file in three positions, namely, vertical, or at 45° to the left or right.

All kinds of rings, including diagonal-cut, step-cut, and angle-cut ones can be filed with the device in question.

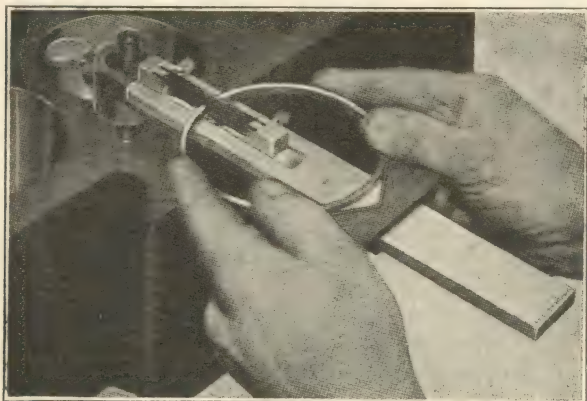


FIG. 86. JIG FOR FILING PISTON RING ENDS

If the ring ends are to be filed by hand, the ring should be held in the lead clamps of the vice and a piece of stick of suitable length inserted so as to open the ring sufficiently to insert the file. A smooth cut file should be used and from time to time the stick should be removed to enable the two

ends to be tested for parallelism. The ring should be tested in the cylinder until the correct gap measurement is obtained. Fig. 87 shows a convenient vice fitting for holding piston rings.

Piston rings must be a good sliding fit in their grooves, with a clearance of 0.001 to 0.0015 in. If slightly on the tight side, they may be reduced by rubbing on a block of wood to which a sheet of emery cloth has been glued; they should not be filed, however, as it is not possible to obtain a satisfactory fit or finish in this manner. If the new ring is a little too wide, it often pays to turn out the piston groove in order to obtain the correct fit.



FIG. 87. PISTON RING VICE

Oil Scraper Rings. Oil scraper or control rings are fitted for the purpose of reducing the oil leakage past the piston to a minimum, whilst ensuring adequate lubrication of the cylinder walls.

All modern pistons have oil scraper rings in the bottom piston grooves; usually there are two (or three) compression rings and one scraper ring. In high-speed Diesel engines two scraper rings are usually fitted. The principle of the scraper ring is to provide a scraping edge so that *when the piston is moving downwards*, the surplus oil is scraped off the cylinder walls and returned to the inside of the piston through holes in the piston walls, whence it drips down into the crankcase.

There are various designs of oil scraper ring, of which the three types shown in Fig. 88 are perhaps the more widely used. That shown at *A* has its upper portion bevelled away. The one depicted at *B* is stepped so that the lower part does not touch the cylinder wall, whilst the scraper ring *C* has a central groove turned, dividing it into two portions which touch the cylinder wall with a clearance space between. Slots are cut through the ring, as shown in Fig. 89, to enable the collected oil to escape to the holes drilled through the back of the ring groove. Oil scraper rings are given rather more radial pressure (against

the cylinder walls) than compression rings, in order to obtain the required scraping action.

Excessive oil consumption in worn engines of earlier model cars can usually be cured by fitting a scraper ring of

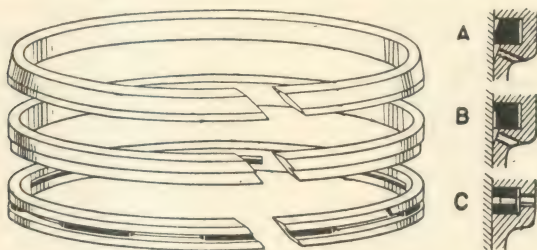


FIG. 88. TYPES OF OIL SCRAPER RINGS (BRICO)

either of the sections shown in Fig. 90 in place of the bottom compression ring.

When fitting scraper rings it is important to place them in their piston grooves the correct way up, so that the scraping

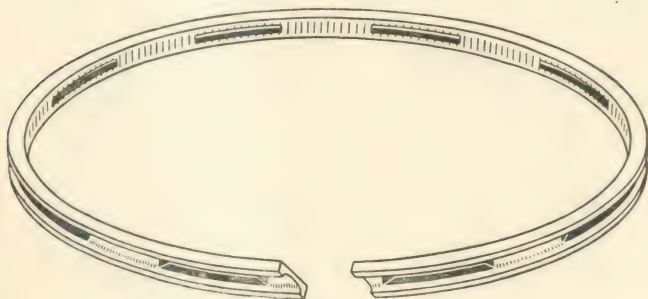


FIG. 89. SLOTTED CHANNEL SECTION RING

edge comes into action only on the down stroke of the piston; further, it is important to arrange for oil return holes of about $\frac{1}{16}$ in. diameter through the pistons, as previously described.

Replacement Compression Rings. In the case of worn engines, where compression leakage occurs, the use of a

special compound piston ring such as the Clupet (Fig 91) or a spring ring of the Wellworthy Simplex type (Fig. 92) will often effect a marked improvement. These rings are

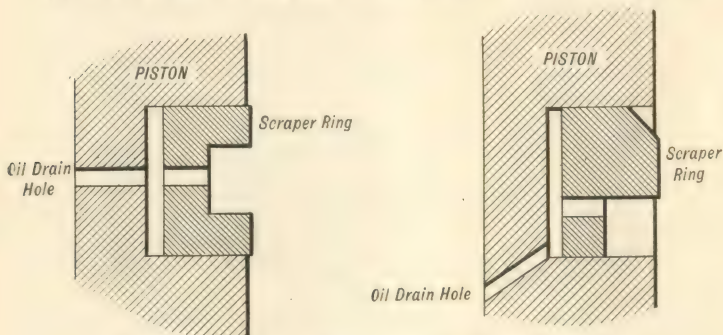


FIG. 90. TYPES OF REPLACEMENT SCRAPER RINGS

designed on the principle that they are sufficiently flexible to adapt themselves to slight irregularities of cylinder bore, such as ovality and taper, and thereby prevent compression loss.

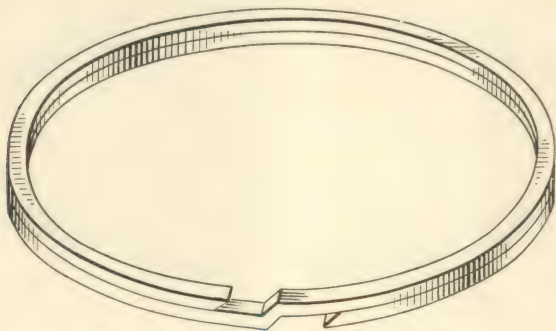


FIG. 91. THE CLUPET COMPOUND RING

The Simplex springs are claimed to adapt themselves to cylinder bores which have worn from 0.010 to 0.015 in. oval or tapered and their use postpones the necessity of a rebore for several thousands of miles.

Another more recent replacement ring is the Wellworthy

"Molium" type (Fig. 93). This is made from a special bearing metal, "Molium," which has low frictional properties. The ring consists of multiple sections (Fig. 93 L.H.)

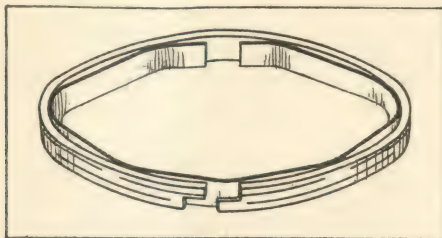


FIG. 92. THE WELLWORTHY "SIMPLEX" SPRING RING

which adjust themselves to the cylinder wall and, owing to the multiple edges, provide good oil-scraping qualities, whilst allowing the spaces between the edges to remain filled with oil, thus tending to reduce ring friction, and

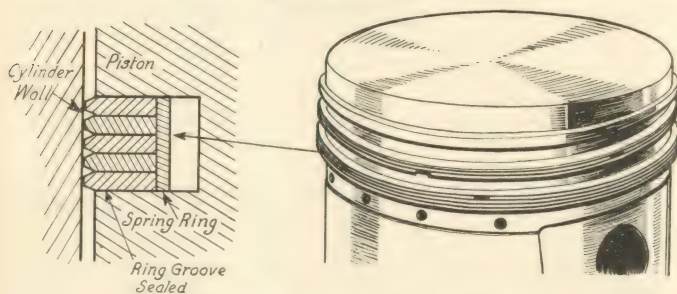


FIG. 93. THE MOLIMUM PISTON RING UNITS

provide a compression or gas seal. The faces of the ring sections are tapered, but the rings themselves are flat in cross-section so as to give a good bearing against each other and also the sides of the piston ring groove. The rings are supplemented by a thin spring steel expander—as in the Simplex pattern ring—and the ring gap is overlapped and sealed by the next section so that no blow-by can occur. Small lugs on the inside of the sections prevent them from

rotating or lining up. The rings are threaded into the piston slots, i.e. not sprung bodily over the piston lands.

It should be pointed out that these rings should not be fitted to the top piston groove, but are recommended for the second and third grooves; for a $\frac{3}{32}$ in. ring groove 3 sections are used; for a $\frac{1}{8}$ in. groove 4, and for a $\frac{5}{32}$ in. groove 5 sections. The gaps should be arranged alternately on opposite diameters and the latter should coincide in

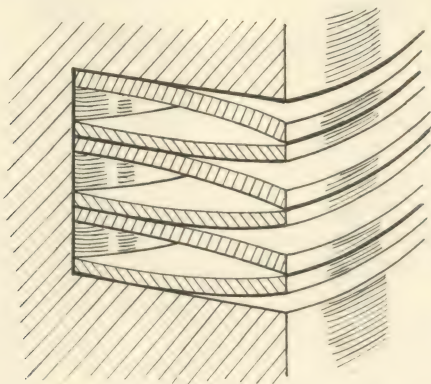


FIG. 94. THE CORDS MULTIPLE PISTON RING

direction with that of the gudgeon pin diameter, i.e. the gaps should be on a diameter at right angles to the piston thrust faces.

In fitting Simplex, Molium, Cords and similar replacement rings it is necessary (1) to remove the unworn ridge at the top of the cylinder barrel, and (2) to machine the piston ring slots square and to the nearest replacement ring dimensions.

The Cords replacement piston ring (Fig. 94) consists of a number of separate cup-shaped spring steel rings which fit securely in the piston slots and by their radial flexibility adapt themselves to cylinder bore variations in worn engines. Each ring element corresponds to $\frac{1}{32}$ in. piston slot depth, so that for slot widths of $\frac{1}{8}$ in., $\frac{5}{32}$ in. and $\frac{3}{16}$ in., 4, 5 and 6 rings would be required. The rings are placed

in the slot by threading them into position; not by expanding the rings and pushing them over the piston lands. When inserting the rings the bottom ring, to be located on the bottom face of the piston slot, should have its concave face upwards. Each successive ring must be reversed in curvature. This rule is true for both even and odd numbers of ring elements.

The recommended individual gap is 0.010 in and, as

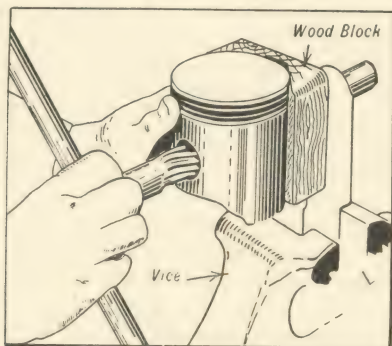


FIG. 95. REAMERING GUDGEON PIN HOLE IN PISTON

with the Molium rings, the gaps should alternate on a diameter parallel to the gudgeon pin diameter.

Cords and similar multiple replacement rings are never fitted in the top piston slot; nor are they advisable in the second slot in the case of engines which run at hotter temperatures than normal for water-cooled engines, since they may then tend to gum up.

Piston Ring Troubles. The various troubles traceable to piston rings are summarized briefly in the following notes and the corresponding remedies are suggested.

Insufficient Gap. Owing to expansion effects, this often results in fractured piston rings with risk of scoring the cylinder walls. Excessive wall friction and oil scraping also occur. The gap should always be checked when fitting rings.

Excessive Gap. This causes a loss of compression and sometimes results in oil leakage past the rings, especially

when scraper rings of correct gaps are not fitted. New rings of correct gap should be fitted.

Compression Leakage or "Blow-by." This may be caused by unequal pressure or bearing of the rings on the cylinder walls, or by excessive ring gaps, owing to wear, faulty design, or improper fitting in the first instance.

The Gudgeon Pin Hole. When reconditioning a piston it is advisable to examine both the gudgeon pin and the holes in the piston bosses and the small end of the connecting-rod.

If any appreciable wear is found in either of these holes it is usual to ream out the hole in the piston bosses and small end and to fit an oversize gudgeon pin to suit. Fig. 95 shows how the piston is held against a wooden vee-block fitting, which is secured in a vice, for the reamering operation.

Fitting Gudgeon Pins. In the case of many aluminium alloy pistons the gudgeon pin is a tight tapping or "thermal" fit in the piston bosses. In order to facilitate the fitting of the gudgeon pin the piston should be immersed in boiling water in order to expand the holes in the bosses, when the gudgeon pin can usually be pushed into place by hand. To prevent distortion of the skirt when refitting gudgeon pins it is a good plan to support the piston on one boss whilst pushing the pin into place from the other side; this refers in particular to cases where pistons are inserted after the connecting rod has been passed through the cylinder bore.

CHAPTER VI

THE CYLINDERS

WHEN the engine has been stripped for examination and overhaul, the cylinders should be inspected for wear and for scoring. The actual car mileages before cylinder bores require reconditioning depend upon such factors as the cylinder design, material used for the casting, the general treatment of the engine since new, decarbonizing periods, kind of lubricating oil, the piston design and material, etc. No hard and fast rules can be laid down, since there must always be a considerable variation in the mileages run by different makes of engine, while much depends upon the manner in which engines of the same make are operated.

The surest guide concerning the necessity of cylinder attention is that of the running of the engine, i.e. whether it fails to develop its full power after the cylinders have been decarbonized, valves reground and clearances adjusted, the oil changed, and so on. Generally, the signs of worn cylinders are loss of compression, excessive oil consumption, smoky exhaust, noisy operation, and appreciable loss of power.

An engine which "smokes" badly upon opening the throttle after idling or after the car has been coasting down a hill with the engine in gear, i.e. being driven by the transmission, may be strongly suspected of having worn cylinders. A temporary cure may sometimes be effected by fitting new compression and oil scraper rings, but if the cylinders are worn appreciably only a partial improvement will be experienced.

Inspecting the Cylinders. When the cylinders have been cleaned thoroughly to get rid of carbon dust and oil, the bores should be examined for signs of scoring by loose gudgeon pins, broken rings, etc.; any longitudinal marks or scratches are sources of gas leakage and oil loss.

Cylinder Measuring Gauges. There are now available several good designs of cylinder bore measuring gauges, of which the Starrett, Ames, Mercer, and Subito dial gauge

instruments are typical examples. The dial pattern is to be preferred to the internal or bar micrometer type since it gives direct readings as the gauge is moved to various parts of the cylinder bore, whereas with the latter gauges

they must be withdrawn each time and the reading taken or worked out.

It is important in the case of dial gauges to ensure that the reading is taken squarely with the axis. In the Starrett and Ames gauges and in certain other specially-designed cylinder gauges there is a "sled" or guide member which ensures that the gauge measuring diameter coincides with the cylinder diameter. The Starrett gauge (Fig. 96) has the plane of its dial gauge perpendicular to the axis of the cylinder and the gauge actually enters the cylinder bore so that, in the lowest position, it is not always easy to read.

The Mercer cylinder gauge (Fig. 97) has an extension spindle which enables the cylinder bore readings to be observed right outside the cylinder. It enables readings to be taken to an accuracy of within $\frac{1}{2}$ -thousandth inch and will measure out-of-roundness and taper. It is self-aligning in the bore and when a diameter measure has to be made the spindle is rocked over the cylinder axis from side to side. The

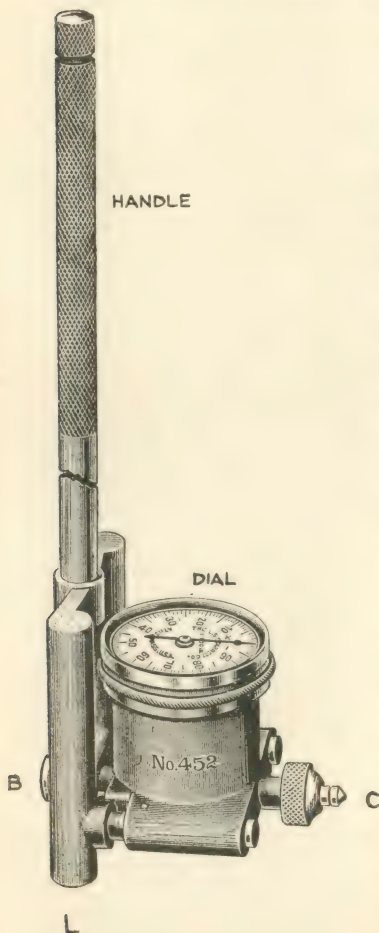


FIG. 96. THE STARRETT CYLINDER GAUGE

maximum dial reading gives the diameter measured. With the aid of distance rods, supplied with the gauge, it is possible to cover a range of cylinder measurements from 2 to 6 in. or 50 to 150 mm. The zero of the gauge can be

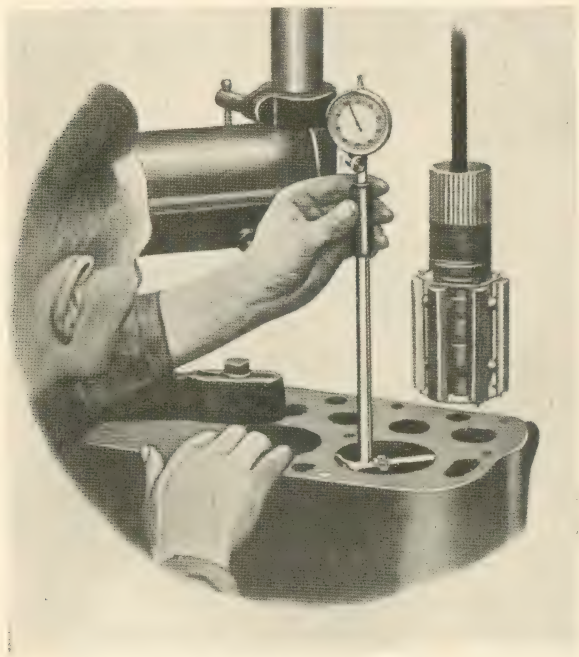


FIG. 97. THE MERCER GAUGE

set opposite to the pointer by means of a movable bezel ring and clamped in this position. The accuracy of measurement of alinement is assured by the three point contact, in addition to the measuring point or plunger.

How to Use Cylinder Gauges. Cylinder gauges can be used (1) to measure differences in the diameter at various parts of the cylinder barrel. (2) To measure absolute cylinder diameters. In the former method it is usual first to ascertain the minimum bore, namely above the top

piston ring position, i.e. the unworn top ridge or near the bottom of the cylinder—where the cylinder wear is least. The dial is then set to zero with the aid of the movable bezel ring and locked in this position. All subsequent readings will then be made as positive differences of measurement in relation to the minimum or practically unworn cylinder diameter. In the latter method, which is used when reboring cylinders for oversize pistons, the gauge is first

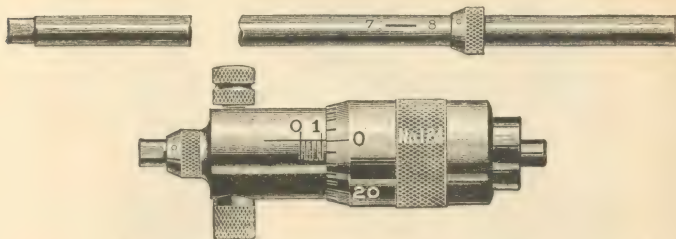


FIG. 98. INTERNAL MICROMETER GAUGE

checked by inserting it in a standard ring gauge and setting the zero of gauge to this measurement. The actual diameter of the cylinder bore is then read off from the dial reading. When using cylinder gauges the bore to be measured should be perfectly clean and the guides and plunger point also.

When not in use the gauge must be kept in its case. Being a precision measuring instrument it should be used with care and not knocked or jarred in any way.

Internal Micrometer Gauges. Cylinder diameters can also be measured with the aid of internal micrometer gauges (Fig. 98) which operate on the same principle as the ordinary shop micrometer, having a movable sleeve and spindle provided with a screw of 40 threads per inch. The barrel is graduated in tenths and fortieths of an inch, one complete turn of the knurled thimble member moving the measuring point through $\frac{1}{40}$ in. The thimble has a scale provided with 25 equal divisions so that one of these divisions equals $\frac{1}{25} \times \frac{1}{40} = \frac{1}{1000}$ in.

Distance pieces accurately ground in length to the dimensions stamped on them enable a wide range of diameters

to be covered. The actual micrometer unit generally has a total range of measurement, in thousandths parts of an inch, of 1 in. or 25 mm.

It is important when using this type of gauge to ensure that it is held at right angles to the cylinder axis; special handles or holders are generally provided for this purpose.

Inside Callipers and Feeler Gauges. The inside calliper method of measuring a cylinder bore is unsatisfactory as it is possible only to measure to within about $\frac{1}{100}$ in. by this "feel" method. Moreover, the results are vitiated by inability to hold the measuring points exactly square with the cylinder axis; by the spring effect of the calliper legs and by the error of transference of the calliper setting to the rule or other method of reading the calliper dimension.

Feeler gauges of the thin narrow flexible pattern are sometimes used for measuring the clearance between a piston and its cylinder, but as modern aluminium alloy pistons are of tapered form it is necessary to know what part of the piston to take the measurements from. In the case of solid, i.e. non-split skirt pistons, the feeler gauge is sometimes used to measure the skirt clearance in the cylinder, when fitting new pistons. The feeler gauge is, however, not considered satisfactory for measurements of clearances in worn cylinders, owing to the variations in the cylinder wear along and across the cylinder.

Nature of Cylinder Wear. When the cylinders of an automobile engine which has been operated for 30,000 to 50,000 miles are measured it is invariably found that (1) in the case of a multi-cylinder engine the maximum amount of cylinder wear varies with the position of each cylinder along the block and (2) the degree of wear varies in different parts of the cylinder along the stroke-axis.

(1) Measurements of typical car engines that have been in service over an appreciable period generally indicate that certain of the cylinders in a block wear much more than others. This is considered as being due to differences in lubrication and temperatures in the various cylinders and to some extent differences in the strengths of the mixture supplied by the carburettor as a result of the particular inlet manifold design employed. In the case of a four-cylinder engine which was stripped down and

measured after it had done 10,000 miles the maximum amounts of cylinder wear for the individual cylinders were as follows—

Cylinder	No. 1 (nearest radiator)	No. 2	No. 3	No. 4
Maximum Wear (inch) .	0.00125	0.002	0.002	0.00175

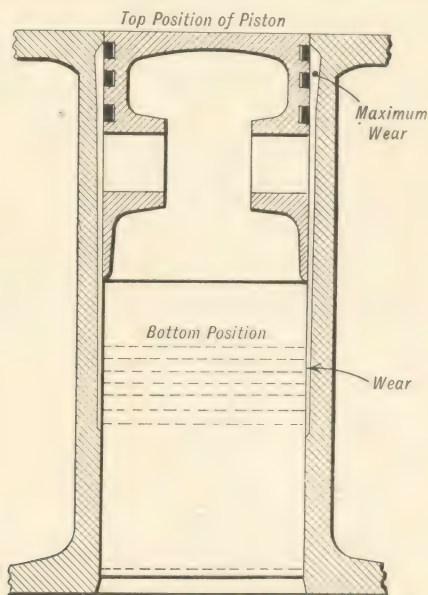


FIG. 99. ILLUSTRATING NATURE OF CYLINDER WEAR

It will be seen that the cylinder nearest the radiator wore the least and the two inner ones the most.

It follows, from these results, that it is necessary to measure all of the cylinders of a worn engine before deciding on the amount of metal to be removed and in connection with the ordering of oversized pistons.

(2) The manner in which the cylinder wears is illustrated in Fig. 99. This shows that the greatest wear occurs at the top of the bore opposite the highest position reached by the top piston ring; there is a practically unworn ridge above this, so that when measuring cylinder bores from the top this fact should be remembered. The amount of wear tapers off to a minimum opposite the lowest point reached by the bottom ring, but there is a certain relatively small amount of wear on the lower skirt position portion of the cylinder. Apart from this tapered wear effect the cylinder also wears more across the thrust faces than at right angles to this diametral position, i.e. the wear in line with the gudgeon pin axis is a minimum.

The maximum wear at the top ring position is usually about four to six times the wear at the bottom position of the top ring. In a typical example, after 50,000 miles the values of the wear for these two positions were 0.0085 in. and 0.0020 in., respectively.

It may be mentioned that in the case of newly machined cylinders the greatest amount of wear occurs over the first few thousand miles rather than subsequently. In this connection the following results of measurements made on an automobile engine are of interest.

Distance run by car	Total wear inch	Miles run per $\frac{1}{1000}$ inch wear
10,000	0.003	3333
30,000	0.007	4285
50,000	0.009	5555
80,000	0.012	6666

These results show that whereas a mileage of 3333 gave $\frac{1}{1000}$ in. wear over the first 10,000 miles, twice this mileage, i.e. 6666 miles, was covered for the same amount of cylinder wear, when reckoned over 80,000 miles.

Amount of Cylinder Wear in Typical Engines. From the engine overhaul viewpoint the total amount of cylinder wear after a certain mileage has been covered is of much importance and in this connection the results of numerous tests made on British automobile engines indicate that

with ordinary cast iron cylinder blocks the worst engines for wear give only about 2000 to 2500 miles for each $\frac{1}{1000}$ in. of wear, whereas the best give from 3000 to 4000 miles, under the most favourable running conditions. Nitrided cast iron cylinder liners give mileages of 12,000 to 20,000 per $\frac{1}{1000}$ in. wear and are therefore much better than plain cast iron cylinders. Heat-treated alloy cast iron liners and porous chromium plated ones usually give from 8000 to 10,000 miles. Austenitic nickel-copper-chromium liners give from 9000 to 16,000 miles per $\frac{1}{1000}$ in. according to the design of cylinder and other factors.

Amount of Wear Before Cylinders Need Reboring. The practical indications of the necessity of reboring a cylinder block are those of general loss of power and excessive oil consumption with a more or less continuously smoking exhaust.

In the case of aluminium alloy pistons when the *total clearance between the piston and cylinder is about 0.007 in. to 0.009 in.* the engine can be given a new lease of life by fitting new piston rings, notably those of the internal spring replacement type, i.e. Wellworthy "Simplex" or the multiple component rings, e.g. Cords and Molium rings.

When the clearance exceeds 0.012 to 0.015 in. the cylinders should certainly be rebored.

The maximum amount of clearance permitted in most commercial vehicle engines is 0.020 in., but reboring should be effected before this figure is reached.

Oversize Pistons for Rebored Engines. Before a cylinder block is rebored the dimensions of the oversize pistons should be ascertained from a consideration of the measured maximum worn diameter in the worst barrel and the amount of metal that must be removed by reboring to just true up this cylinder.

Thus, if maximum worn diameter = $2.750 + 0.015$ in. and amount to be removed by truing and finish honing is 0.015 in., the finished cylinder diameter is given by—

$$\begin{aligned}\text{Machined final diameter} &= 2.750 + 0.015 + 0.015 \text{ in.} \\ &= 2.780 \text{ in.}\end{aligned}$$

The nominal diameter of the oversize pistons will therefore be 2.780 in. If this is not a stock size then the cylinder

barrels will have to be rebored and finished to the next larger size available.

Oversize pistons are generally supplied for mass-produced engines in diameters greater than the original or new engine piston diameters by 0.0075 in., 0.010 in., 0.015., 0.020 in., 0.030 in., and 0.040 in. It should be noted that when an oversize piston is ordered from the engine manufacturers or from specialist firms of piston manufacturers, the *nominal diameters stated in the firm's catalogues* are those of the *finished rebored cylinder diameters* and therefore *include the correct working clearances*. Actually, the piston diameters are less than the nominal sizes listed by the amounts of the clearances, but it is more convenient to order them by the cylinder diameters for which they are required. The cylinders should be bored to the nearest standard oversize required *with a tolerance* of minus 0.0000 and plus 0.0005 in. The *actual minimum clearance* at the bottom of the skirt for split pistons should be 0.00075 in. per inch of diameter, and for solid skirt pistons 0.001 in. per inch. Usually a cylinder block can be rebored twice, so that if a third rebore is subsequently required it is *necessary to fit a cylinder liner*.

Methods of Truing Worn Cylinders. There are various alternative methods for truing worn cylinders. These include *honing, grinding, boring with cutters, reaming, and lapping*. In considering the actual method to be adopted, the available equipment and the nature of the finish required must be taken into account.

The modern practice in the larger garage workshops is to employ cylinder grinding machines of the Churchill type, so that the finish obtained is similar to that of new cylinders. Many large motor repair works use the cylinder hone and the boring cutter methods, however; in each case the work is done on special machines of rigid construction designed specially for the purpose; these should not be confused with the portable and hand machines used on motor chassis.

The surface finish obtained with the boring bar method is not so good as that of the grinding or honing methods, so that it is usual to finish the cylinder barrels with a honing device to remove the fine cutter marks. Sometimes honed

or ground cylinders are given a high degree of surface polish with a special copper or lead lap, using a very fine grade of carborundum mixed with mineral oil. In other instances the cylinders are finished with a hardened polished roller, used after the manner of an internal grinding wheel.

The Honing Method. This method belongs to the grinding class and employs a number of grinding stones, namely from four to six, mounted radially in a special holder and arranged so that the stones (or hones as they are termed) can be moved in or out by means of a micrometer device to decrease or increase the diameter. Most cylinder hones for motor-car and vehicle engines are adjustable from about $2\frac{1}{2}$ to $5\frac{1}{2}$ in. in diameter.

It should be emphasized here that lapping or honing alone will not correct out-of-roundness in the cylinder bore, so that it is necessary first to rebores with a tungsten carbide cutting tool, or to employ an expansion type of reamer to true the bore.

The honing machine may be of the fixed machine shop type or portable. In the former kind, of which the Kitchen & Wade machine is an example, the cylinder block is mounted on the machine table; in the latter the machine is operated by an electric motor of $\frac{1}{2}$ to $\frac{3}{4}$ h.p. and is made portable so that it can be used without removing the cylinder block from the chassis. Examples of portable honing machines are the Hall, Ammco, and Newton-Hartridge.

Cylinder hones are usually rotated at speeds ranging from 400 to 700 r.p.m. and while revolving are fed into and out of the cylinder barrels a number of times; in some cases a constant reciprocating movement or "stroking" action is given to the hone automatically.

The hone is reciprocated up and down at the rate of 50 to 125 strokes per min. according to the type of machine.

The honing stones are supplied in different grades for roughing, ordinary truing operations, and for finishing; the finer grades of stone are used for the latter purpose.

It is necessary to run the finer grades of honing stones at a higher speed than for the coarser stones.

Roughing operations are carried out with the stones

kept "dry," but finishing operations are done with paraffin or soapy water as a cutting lubricant.

The micrometer adjustment provided with most honing machines enables the diameters to be varied by $\frac{1}{1000}$ in. at a time. The roughing process is done with cuts of $\frac{2}{1000}$ to $\frac{4}{1000}$ in. and the finishing with a cut of about $\frac{1}{1000}$ in. It is usual to repeat the finish honing operation to enable the "spring" of the stones to provide the final light honing pressure which is necessary to obtain the smoothest finish.

For cylinder-truing operations it is usually necessary to remove with the roughing and finishing hones about $\frac{7}{1000}$ to $\frac{10}{1000}$ in. of cylinder metal in all, the average time being from twenty to thirty minutes per cylinder barrel.

A well-designed cylinder honing tool will leave the cylinder bore accurate in cylindrical shape to within $\frac{1}{4}$ to $\frac{1}{2}$ -thousandth inch and not more than the same amount tapered over the usual automobile engine lengths of stroke.

The Ammco self-lubricating honing machine (Fig. 100) has a range of $2\frac{3}{16}$ to 4 in. and employs four hones; a micrometer adjustment is provided.

The hones are impregnated with a dry lubricant so that the abrasive dust does not fly about as in ordinary cases and no vacuum cleaner is therefore required to control the dust and prevent it from reaching the rest of the engine. A special surfacing hone is also made for finishing cylinders in about thirty seconds. The hones are expanded automatically to fit the cylinder barrel and remove the bare minimum of surface metal.

When alining cylinder hones it is usual to use the unworn ring of metal at the top of the cylinder block for locating purposes; special care is necessary to ensure that the axes of the hone and of the cylinder barrel coincide. The slightly contracted hone should be lowered into the cylinder barrel and measurements taken at each end to ensure concentricity of the hone and barrel; alternatively, the hone can be located from the machined cylinder head face.

The Grinding Method. The operation of cylinder grinding can be done either on a lathe of suitable design and rigidity or on a special machine designed for the purpose—similar to that used by car engine manufacturers.

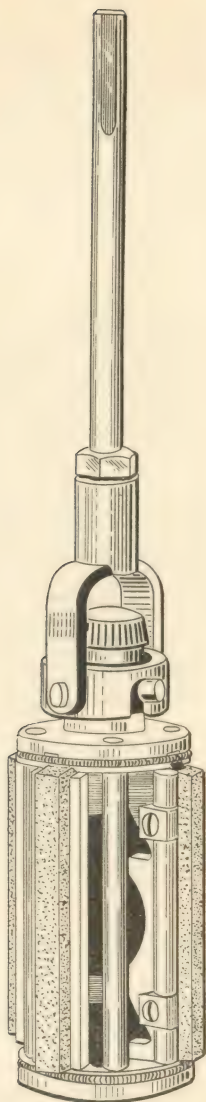


FIG. 100. TYPICAL ADJUSTABLE CYLINDER HONE

The principle of the method is to use a small grinding wheel of diameter a little greater than one-half the cylinder diameter. This wheel is rotated at a suitable speed to give a linear cutting speed of about 4500 to 5000 ft. per min. The cylinder is either arranged to rotate slowly in the

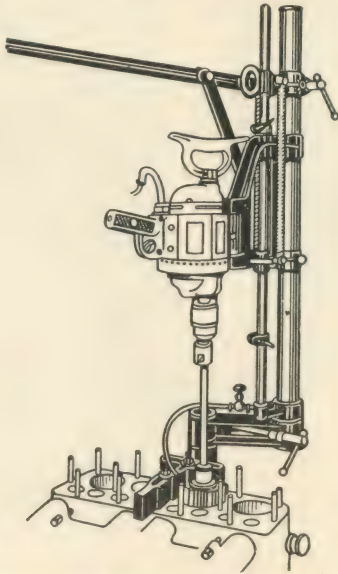


FIG. 101. ELECTRIC HONING MACHINE, WITH HAND STROKING ATTACHMENT

opposite direction—to that of the grinder—usually from 40 to 60 ft. per min., or the axis of the grinding head is given a concentric movement so as to traverse all of the cylinder barrel as the wheel is fed into the latter. The advantage of the latter method is that the cylinder block can be kept stationary on the machine bed. The wheel cutting feed is provided for by altering the eccentricity of the wheel axis in relation to its spindle, so as to vary the cutting radius. The grinding wheel can thus cut a larger bore than its own diameter while the feed can be adjusted

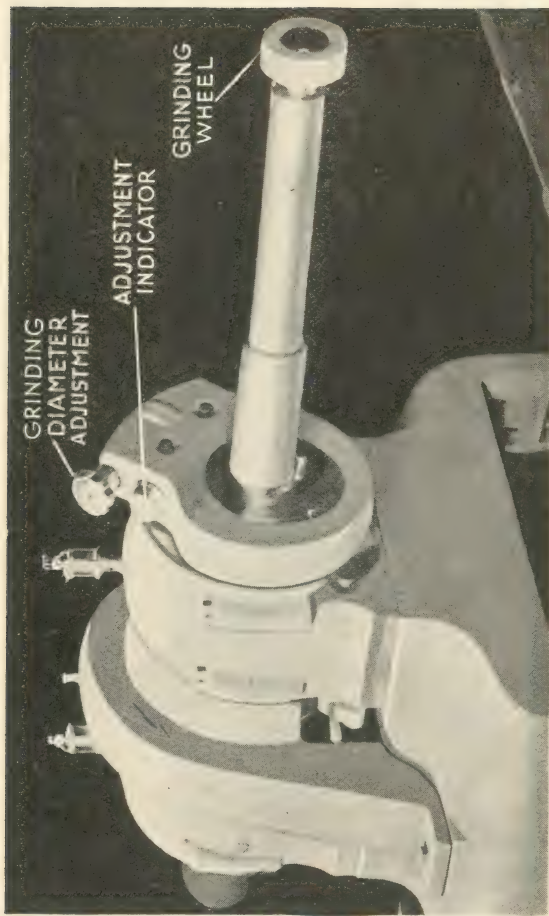


FIG. 102. TYPICAL CYLINDER GRINDING HEAD, WITH ECCENTRIC ADJUSTMENT FOR GRINDING DIAMETER (HEAD)

to within $\frac{1}{8}$ -thousandth inch in most designs of grinding head (Fig. 102).

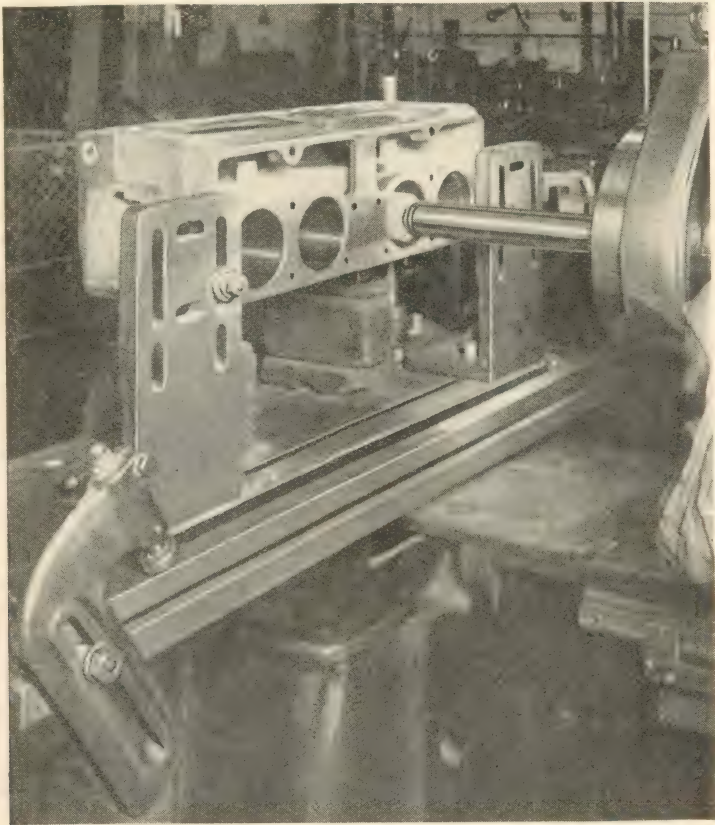


FIG. 103. GRINDING A FOUR CYLINDER ENGINE BLOCK

The usual design of grinding head provides an overhung spindle of great rigidity with ball or roller bearings at the two ends, provided with suitable lubrication means so that the shaft can run at high speeds of the order 10,000 to 20,000 r.p.m.

When using such grinding heads only light cuts should be given. Thus, for the first or cleaning cuts about $\frac{.3}{1000}$ to $\frac{.4}{1000}$ in. should be removed feeding in and $\frac{.2}{1000}$ in. when feeding out. The next feed-in cut should be about $\frac{.2}{1000}$ in. and feed-out cut, $\frac{.1}{1000}$ in. The final in and out cuts should be made without any further feed, to allow the wheel to give the best possible surface finish.

The correct grade of wheel must be selected to suit the nature of the metal; wheel manufacturers, e.g. Messrs.

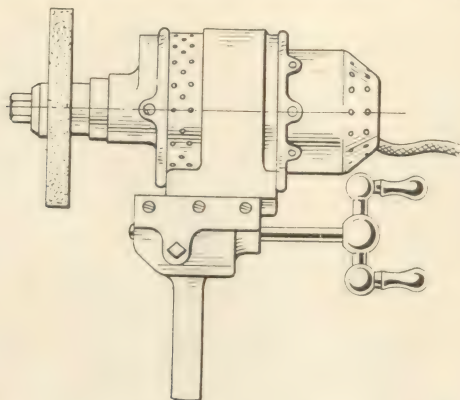


FIG. 104. LATHE TOOL POST ELECTRIC GRINDER

Carborundum Co. Ltd., Manchester, and Messrs. Norton Ltd., Letchworth, Herts, will always advise on the proper grade and bond to be used.

The grinding head should carefully be alined so as to grind the cylinder barrel truly. It is best after alining the head to take a light trial cut to test the accuracy of the setting.

Cylinders should always be *ground in the dry state*, since the finish obtained is better than for wet grinding.

The grinding wheel wears very slowly, only about $\frac{1}{2}$ -thousandth in. being worn after grinding the usual four-cylinder block. It is advisable to *true the wheel* at certain intervals with a *diamond tool*.

It is also important to remove the grinding dust with a

suction type exhausting fan arranged at the rear end of the cylinder block.

Finally, do not allow the cylinder *to become too hot* while grinding, or inaccurate results will be obtained.

The Boring Bar Method. In recent practice the method of truing worn cylinders with the boring bar has become widely used on account of its rapidity and precision. The method consists in fixing the cylinder block to the table of the machine and boring it with a tungsten-carbide tipped cutter (or cutters) mounted on a large diameter boring head of massive and rigid construction. Provision is made for accurate setting of the cutter, by means of a micrometer attachment and also for the sharpening of the cutters on a diamond dust impregnated disk mounted on the machine.

For motor repair purposes portable boring bar machines have been devised, such that they can be mounted on the machined head of the cylinder block for boring the cylinder barrels in position, on the chassis. Typical examples of such boring machines are the Buma "Storm," Van Norman "Perfecto," Mansion's K.B., Thomasson and Hall's; these all operate on the same principle and are driven by means of electric motors of about $\frac{1}{4}$ h.p. each.

Fig. 105 shows the Buma "Storm" cylinder boring machine which is operated from a $\frac{1}{4}$ h.p. 50-cycle electric motor. The various parts lettered are given in the key below the illustration. Special features of the machine include a diamond sharpening disk for the cutter; automatic stop switch when bar has finished cut; screw feed with quick return of cutter bar by rack and pinion; hardened main bar of $2\frac{1}{8}$ in. diameter; two-speed drives; detachable motor; easy clamping device for using on adjacent cylinder; and tungsten-carbide cutter with micrometer setting. The machine has a boring diameter capacity of 2.2 to 4.2 in. and depth up to 10 in.

Another type of cylinder reconditioning machine consists of the usual boring bar tool and in addition a grinding spindle driven at a suitably high speed by a belt or gears. After the cylinder has been bored the surface is finished at the same setting with the grinder, an automatic feed being provided for both the boring head and grinding wheel.

In most boring machines there is an adjustable stop or trip device which switches off the driving motor when the cutter reaches the bottom of the cylinder.

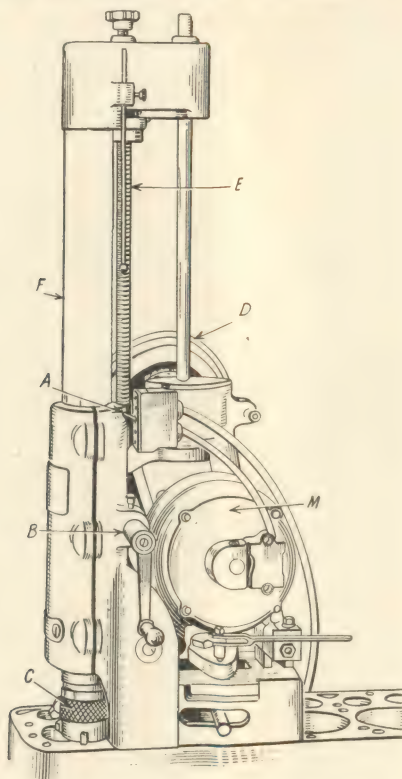


FIG. 105. THE "STORM" CYLINDER BORING MACHINE

- | | |
|-----------------------------|--------------------------------|
| A = Automatic stop switch | D = Diamond sharpening disk |
| B = Handle for quick return | E = Screw feed for cutter head |
| C = Cutter head | F = Main bar |
| | M = Electric motor |

Boring bars of the car engine cylinder type are operated at speeds of 300 to 400 r.p.m. and are provided with automatic screw-operated or hydraulic feeds of 1 to 2 in. per minute in the axial direction.

With these bars cuts up to about $\frac{50}{1000}$ in. can, if necessary, be taken. The cutter diameter is generally made

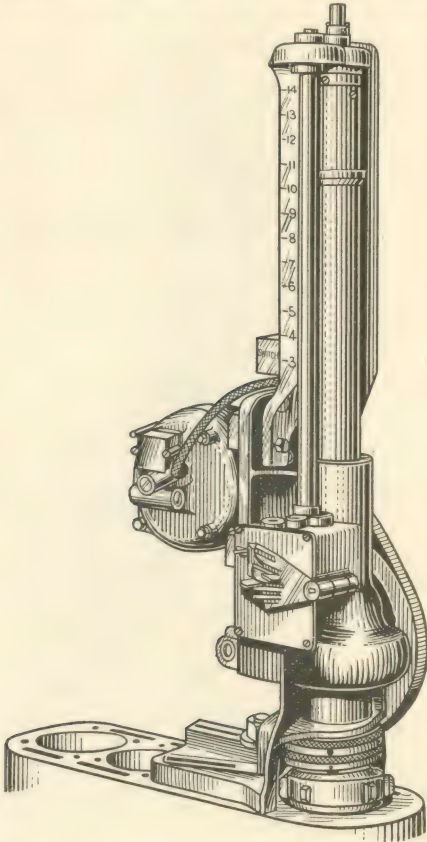


FIG. 106. THE HALLS CYLINDER BORING MACHINE

This is electrically operated and employs a six-cutter boring bar

adjustable for a range of about 2 to $4\frac{1}{2}$ in. in standard pattern boring bars.

The average time required to recondition a worn cylinder is from twelve to fifteen minutes with a properly designed boring bar.

The Cent-Ro-Mac cylinder boring machine* illustrated in Fig. 107 embodies certain novel features. These include

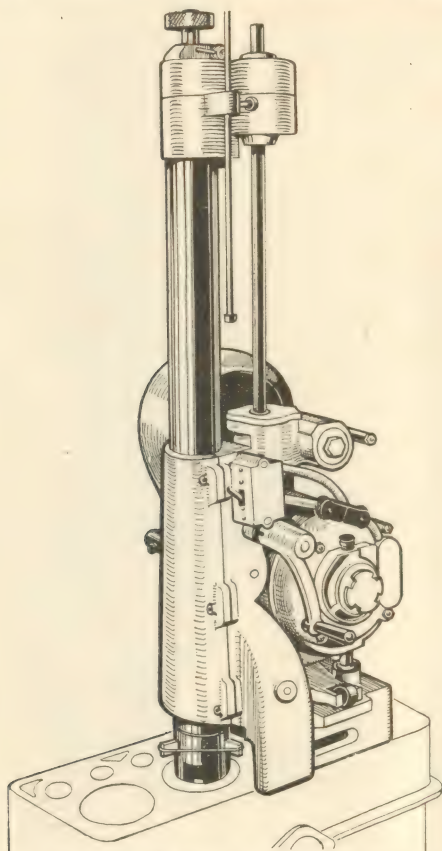


FIG. 107. THE CENT-RO-MAC CYLINDER BORING MACHINE

a cutter head and high speed spindle mounted on Timken bearings, the cylindrical hardened steel bar being guided through the cylinder bore by the base casting which is of particularly rigid construction. The machine is readily

* Buma Engineering Co. Ltd.

set on the cylinder block by lowering the main bar into the bore. The centring blades are then expanded by operating a handwheel at the top of the gearbox. The feed mechanism for the tool bar or cutter holder is by means of an Acme-threaded spindle with which a long solid phosphor-bronze nut engages. By means of a small lever, provided for the purpose, the feed can be engaged and disengaged whilst the machine is running.

Three cutting speeds are provided for the cutter, namely, 460, 320, and 180 r.p.m.; these are suitable for small bores,

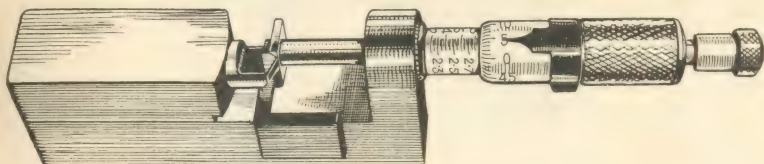


FIG. 108. MICROMETER UNIT FOR SETTING CUTTER

large bores and hard surface bores, respectively. The cutter holder carrying the tungsten-carbide tipped tool can readily be mounted on the micrometer unit and the cutting diameter set to any desired dimensions away from the machine. The micrometer unit (Fig. 108) carries a pin that accommodates and therefore locates the cutter holder, which has a corresponding locating hole for this purpose. It is necessary, therefore, only to fix the micrometer in the cutter adjuster, push out the cutter to contact the end of the spindle on micrometer and then lock the cutter. The boring machine has a range of 2.2 in. to 4.2 in. diameter by 10 in. length. It is operated by a $\frac{1}{4}$ h.p. A.C. motor mounted on a three-point suspension, and can quickly be removed and replaced should an electrical fault develop; the detachment of the motor takes only about ten seconds. Cutter sharpening jigs, to ensure the correct cutting angle and clearances, are provided and there is a diamond lap for touching up the cutter.

Cutters for Boring Bars. The tungsten-carbide synthetic alloys employed possess much better cutting properties and last much longer than high speed steel cutters; they may be

operated at fairly high cutting speeds, but, being of a more brittle nature than steel, should be used with appreciably lower cutting pressures.

Typical synthetic cutting alloys used for this purpose are Ardoloy, Wimet, and Carboloy. Stellite is also used for similar purposes.

Since these materials are relatively expensive it is usual

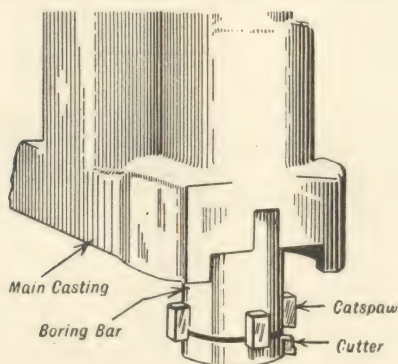


FIG. 109. THE VAN NORMAN BORING HEAD

to employ steel shanks or cutters tipped with these alloys by a brazing process.

Owing to their great hardness they will give long service before any resharpening becomes necessary. Thus, there will be no measurable wear during the boring of a cylinder, so that the initial and final diameters will be identical.

Boring Bar Notes. When using the boring bars described great care is necessary to ensure correct location of the cutter. In some cases a locating disk is provided, such that when the bar is adjusted so that the disk just centralizes in the mouth of the cylinder barrel the axis of the boring bar will be coincident with that of the cylinder.

In the Van Norman boring bar there is a four-armed support situated about $\frac{1}{2}$ in. behind the cutter, known as the "cat's paws" support (Fig. 109). These arms can be extended or contracted to suit the cylinder diameter; their duty is to steady the cutter and also to centralize the boring bar in the cylinder.

From previous measurements of the worn cylinders of a block the final size for boring all of the cylinders is decided, taking the barrel having the greatest wear as the standard; all the other cylinders are then bored to the size of the trued-up standard one.

It is usual first to take a roughing cut of $\frac{3.0}{1000}$ to $\frac{5.0}{1000}$ in. —according to the amount of unequal wear in the cylinder

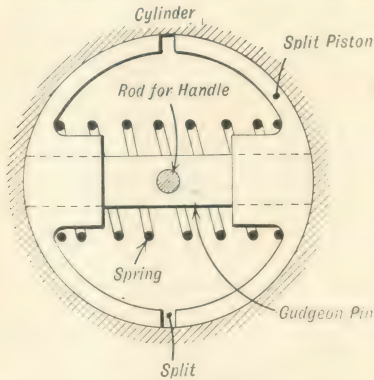


FIG. 110. A CYLINDER LAPPING DEVICE

—followed by a finishing cut of $\frac{2}{1000}$ to $\frac{4}{1000}$ in. with a fine feed.

The boring on cast iron cylinders is done in the *dry condition*.

Improving the Finished Bore. *The appearance of the finished bore* is such that it shows a very light tool mark of a spiral nature corresponding to the feed path of the cutter. A microscopic examination of the surface reveals a series of minute crests and furrows, such that when wear eventually occurs in the cylinder the crests will be reduced and the piston clearance increased thereby.

In the best practice, cylinders which have been trued with boring bar cutters are given a final honing, using a fine grade stone with paraffin as a lubricant. Only about $\frac{1}{1000}$ to $\frac{2}{1000}$ in. of material is removed by this process; a much smoother finish is thereby obtained. Alternatively, bored cylinders may be given a high degree of smoothness

and polish by means of a *lead* or *copper lap* of slightly smaller diameter than the cylinders themselves. The surface of the lap is charged with a wet mixture of thin oil or paraffin and fine carborundum powder, the lap being rotated at a fairly high speed and worked up and down the cylinder. If the lap is of the split pattern with springs to give the necessary light radial pressure better results

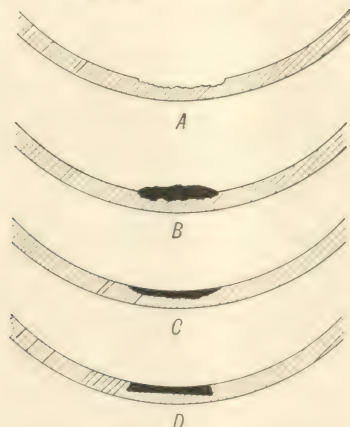


FIG. 111. METHODS OF REPAIRING SCORES IN CYLINDERS

- A = Cylinder score
- B = Nickel or hard solder deposit
- C = Deposit scraped flush with cylinder wall
- D = Repair by dovetailing and swaging hard alloy strip into position

will be obtained than with the plain lap (Fig. 110). It should be pointed out that hand lapping is usually a somewhat lengthy process.

Worn cylinders cannot be trued by the lapping process, however, since the lap adapts itself to the shape of the bore to a certain extent and, if the latter is oval, will merely increase the degree of ovality.

Another method of improving the surface finish of rebored cylinders is to employ a hardened burnished roller mounted on an eccentric head similar to that of the internal grinder previously described. This roller is pressed against the cylinder barrel as it revolves and is fed spirally into it.

Repairing Scored Cylinders. Cylinder walls that have become scored owing to broken rings or loose gudgeon pins may be repaired by one of the following alternatives.

(1) *By Electro-deposition.* The scored part, after the thorough cleaning and chemical treatment, usual with steel parts preparatory to plating, is given a coating of nickel of sufficient thickness to enable the score to be filled slightly

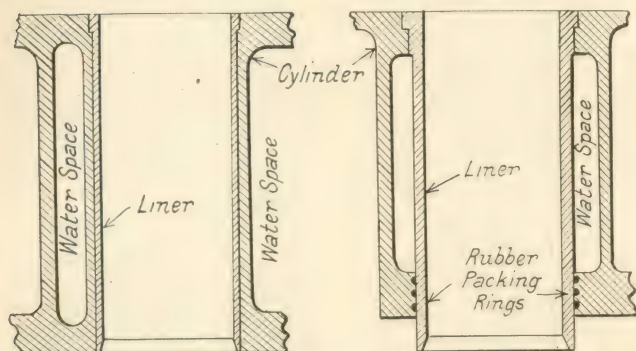


FIG. 112. (Left) DRY LINER. (Right) WET LINER

above the wall surface. The surplus nickel is then removed by scraping with a cylindrical tool. The unscored part of the cylinder is painted over with a protective material so that no nickel will adhere to it during the plating process.

(2) *By Soldering.* The bottom of the score is copper plated and, after preheating the cylinder block, the score is first tinned and then given a sufficient deposit of a hard high melting point solder to rather more than fill the groove. The surplus metal is scraped off so as to leave the filled groove quite smooth and cylindrical.

(3) *By Dovetailing Metal Strip.* In this method the score is machined with a cutter which will give a dovetail shape and a strip of copper nickel alloy is inserted into the groove, afterwards rolling it down so as to expand and fill the groove completely.

(4) *By Silver Soldering.* This process resembles that given in (2), but necessitates preheating the cylinder block to a higher temperature, namely, sufficient to enable the

silver solder to melt. The complete block should be preheated in an oven, otherwise temperature stresses or distortion may occur afterwards.

Cylinder Liners. It is possible to extend considerably the life of a cylinder block by the method of fitting liners of hard cast iron or steel, so that a much harder and therefore longer wearing surface is presented to the piston. There are two types of cylinder liners in use on motor vehicle engines, namely, the *dry* and *wet* ones (Fig. 112).

The wet type of liner, as its name implies, is exposed to the cooling water on its outer surface, whereas the dry type is inserted into the cylinder barrel and is therefore surrounded, externally, by the metal of the barrel.

Wet liners are generally made of a special chromium or nickel chromium cast iron and are heat-treated in order to obtain the maximum hardness. They are cast by the centrifugal method so as to secure freedom from inclusions, such as gas cavities.

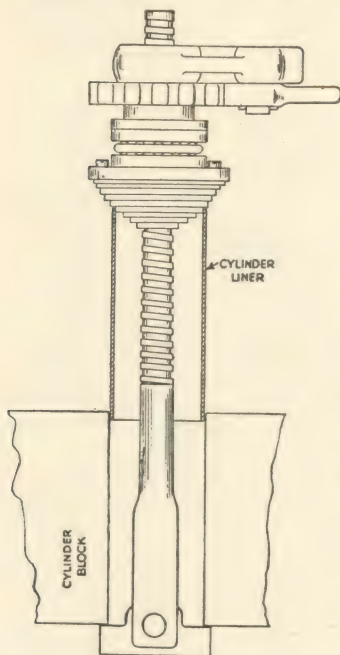


FIG. 113. THE BUMA CYLINDER LINER TOOL, SHOWN INSERTING A LINER

The usual method of making the joint is by means of two or three rubber packing rings below, the stepped top fitting into a recess bored for the purpose in the top of the cylinder barrel. It is the practice to make this portion and the part containing the rubber rings a good push fit in the cylinder block.

To fit a wet liner, after ensuring that the rubber rings are in fresh condition, i.e. not perished, it should be well

smeared externally with soft soap and then pressed down, by means of a light press, into the block. The top of the liner is finally held in position by the cylinder head.

To remove a wet liner, which will probably be found to have become tighter than when it was first fitted, it may

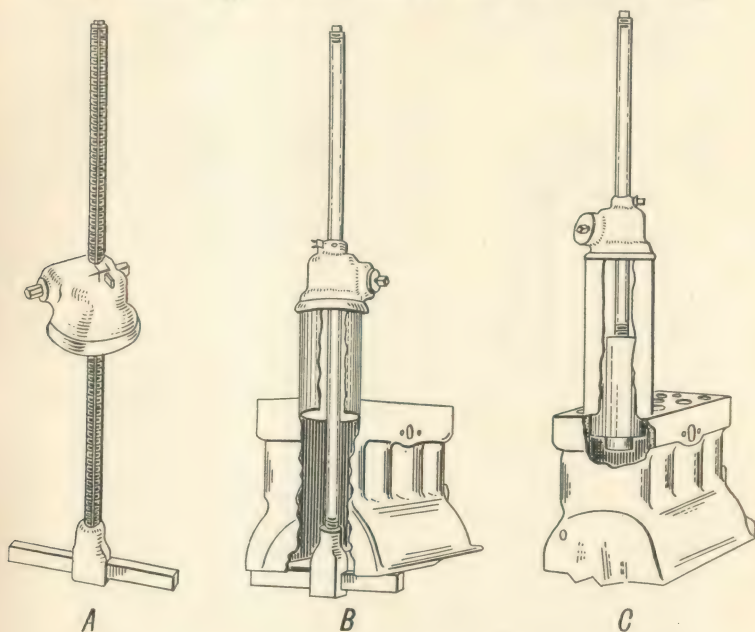


FIG. 114. THE OHIO CYLINDER LINER TOOL

be necessary to use a screw press tool, such as the Buma or Ohio. The former type (shown in Fig. 113) can also be used for inserting wet or dry liners. It has a ratchet and pawl operated nut, provided with a ball thrust bearing, so that the nut rotates around the square-threaded shank member, thereby raising or lowering, but without rotating it.

Fig. 114A shows the Ohio liner insertion and extraction tool. It consists of a long square thread with worm and wheel operated nut, a squared shaft on the worm being used for the operating handle. At the base is fitted a bar

of suitable length to bridge the lower part of cylinder as shown in Diagram (B). The same tool can be used for removing liners; in this case, as shown in Diagram (C), it is necessary to use a larger size sleeve on top and a disk or bar below, of such a diameter that it is slightly less than the outside diameter of the liner.

The dry type of liner is usually from $\frac{1}{16}$ to $\frac{3}{16}$ in. thick according to the cylinder bore. It is made an interference fit in the cylinder block, the outside diameter of the sleeve being from 0.001 to 0.004 in. greater than that of the cylinder block bore, according to the diameter ($2\frac{1}{2}$ to 6 in.).

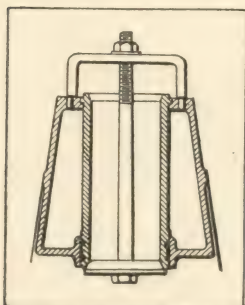


FIG. 115. REMOVING
WET TYPE CYLINDER
LINER

Inserting dry liners. These are inserted in three different ways, namely, (1) by means of a screw press tool similar to that shown in Fig. 115, (2) by means of an hydraulic press (Fig. 116), or (3) by the liquid air or oxygen shrinking process.

In the latter method the liners are inserted into a refrigerator surrounded by *liquid air or oxygen*, in order to shrink them by a few thousandths of an inch. They are then transferred quickly to the cylinder block, where they take up the air temperature of the latter and become very firmly fixed, so that they will never loosen under any working conditions.

In the case of a cylinder liner of 3 in. outside diameter, immersed in liquid oxygen at -180°C . with the cylinder block at the usual air temperature of 20°C ., the total shrinkage is 0.007 in. If the cylinder block is warmed a greater shrinkage difference is obtained. However, as the interference fit is usually 0.002 to 0.004 in. the above method gives ample clearance for the rapid insertion of the cold liner.

When an *hydraulic press* is employed, the pressure is such that the liner is forced into the cylinder block with a force of 4 to 8 tons. The initial force is much smaller, however, but as the liner enters the block the resistance

increases, so that the pressure must also be increased gradually to overcome this resistance.

Motor car cylinder barrels which have become much worn can be bored out with a tungsten-carbide boring bar and

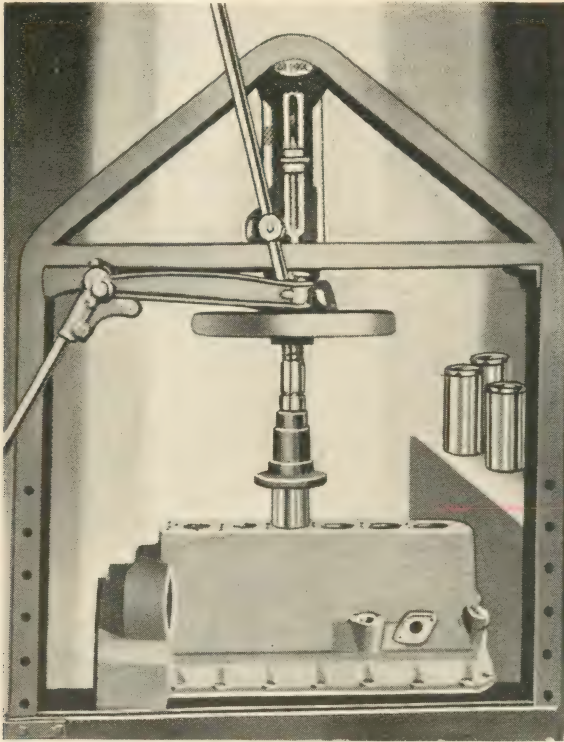


FIG. 116. HYDRAULIC PRESS FOR INSERTING LINERS IN CYLINDER BLOCKS

liners of alloy cast iron or Nitralloy of about $\frac{1}{16}$ to $\frac{3}{8}$ in. thickness forced into the barrels. In this way the old pistons can be used again, whereas with rebored cylinders oversize pistons are necessary.

Nitralloy Cylinder Liners. Nitralloy is a class of special

alloy steels, containing, besides chromium and nickel, certain other elements, including aluminium and molybdenum.

These steels possess the property of acquiring an extremely hard skin, resembling—but much harder than—that of case-hardened steel. The hardening method, known as *nitriding*, consists in heating the liners or other parts to the comparatively low temperature of 500° C. in a stream of ammonia gas, the nitrogen of which gives the extreme surface hardness to the steel.

The depth of the hard skin is usually from $\frac{1}{2}$ to 1 mm. after about 60 hours to 100 hours' exposure to the ammonia.

Liners made of Nitralloy will give road mileages of 80,000 to 100,000 miles before replacement becomes necessary; moreover, they can be given a high degree of surface polish.

Finishing Cylinder Liners. The ordinary dry cylinder liner is usually ground to within 1- or 2-thousandths of its required inside dimension. After insertion by the press or shrinkage methods previously mentioned it is found that a small amount of shrinkage and, occasionally, a slight distortion may occur to the inside diameter.

It is therefore the practice, after inserting dry liners, to finish the bores to the final dimensions by means of a honing operation, using a fine grade of hone for this purpose. For finer polished finishes, the lapping or buffing process is generally employed.

With the wet type of cylinder liner no final honing or lapping operations are necessary, since no shrinkage or distortion occurs during their insertion.

In the case of nitrided cylinder liners, which are extremely hard, a method used for aircraft engine liners of glass-hardness, which could not be honed by ordinary silicon carbide honing stones was to employ bakelite-bonded diamond-impregnated hones. These gave excellent results in regard to cylindricity and fine surface finish. A rotational speed of 75 r.p.m., for the $5\frac{3}{4}$ in. diameter hone, with 30 strokes per min., using a mixture of 65 parts paraffin and 35 parts lard was found to give the best results.

Detailed Instructions for Fitting Liners. Although a good deal of useful information has been given on this subject in the preceding pages, the following details and

instructions for fitting dry liners of the Brico type will illustrate the general method more clearly.

The Brico cylinder is made of centrifugally chill cast nickel-chromium alloy cast iron suitably heat-treated to give a hardness of 400 to 500 Brinell—a value over twice as hard as for ordinary cylinder block irons. With such liners the life of the cylinder is greatly increased, before the effects of wear necessitate the fitting of new liners, i.e. 12,000 to 20,000 miles per $\frac{1}{1000}$ in. of wear.

The liners are made in outside diameters of 2 to $7\frac{1}{2}$ in. A typical range for car engines is 2 in. to $3\frac{1}{2}$ in., the thickness being about $\frac{5}{64}$ in. For the $3\frac{1}{2}$ in. to $4\frac{1}{2}$ in. diameter range the thickness is $\frac{3}{32}$ in.

The cylinder barrels are bored out to the outside diameter of the liner minus 0.0005 in. to minus 0.001 in.; this ensures the necessary interference fit mentioned previously. When boring the cylinder block a tungsten carbide cutter should be used, the cutting edges being kept keen by dressing on a diamond-impregnated lap. The cutters are set to $\frac{1}{2}$ to 1-thousandth inch less in diameter than the outside diameter of the sleeve for the finishing cut. Alternatively the cylinder barrels can be honed to size. The liner itself can be used as a gauge; the liner is provided with a "lead-in" portion which should be a push fit in the finish-machined bore to ensure a correct interference fit between the liner and the cylinder barrel.

Next, the cylinder bore and outside diameter of the *liner should be smeared with engine oil, soft soap or white lead* to ensure the liner being pressed home without any chatter and with the minimum of effort. The lead-in portion should then be inserted into the top of cylinder barrel and the liner pressed down into the barrel by means of an hydraulic or screw press—or with one of the liner insertion tools described previously. After the liner has entered by 1 or 2 in., release the load in order to allow the liner to correct any mis-alinement. Then press the liner home flush with the top of the cylinder block. The press used should give a steady jerk-free downward action; if the movement is jerky there is a risk of cracking the liner.

The cylinder bore (inside diameter of the liner) *will close in by approximately three-quarters of the interference*

fit when the liner is fully inserted so that it is necessary to *hone out the cylinder bore*. In view, however, of the liner being soft for an inch or two at the bottom (this is for the purpose of cutting connecting rod clearance slots, when necessary) it is advisable to finish honing the bottom of the liner first, so that the hone will not "pick up" when travelling from the hard to the soft section, thus making the latter portion oversize.

It will be found that the amount left in the bore of the liner to be honed out is about 0.003 in. (maximum). On the average this requires about 15 minutes per bore to remove. The following grades of honing stone are recommended.

For Wet Honing.

Carborundum Limited

Roughing	. 120 Grit 6 H.	. or 180 Grit 4 H.
Finishing	. 2 F.G.3.H.	. or 4 F.W.H.

For Dry Honing.

Ammco impregnated self-lubricating stones.

Coarse stone for roughing cut.

Burnishing stone for finishing.

Dry honing is very suitable for honing the liner bores with engine in chassis as it is not necessary to use any paraffin.

Salvaging Worn Cylinders. A method of salvaging worn cylinders, employed by Messrs. Rolls Royce Ltd. for aircraft engine cylinders, is applicable when the maximum wear does not exceed 0.020 in. It consists in depositing chromium direct on to the cylinder wall for a distance from the top of about one-third of the piston stroke. The cylinder is then rebored to a maximum oversize of plus 0.012 in. and new pistons and rings are fitted. After a further long period of service the cylinder can be replated without reducing the cylinder wall thickness to the extent of an ordinary rebore or repeated rebores.

Repairs to Cracked Cylinder Blocks. It is now the usual practice to execute repairs to cylinder blocks that have become cracked as a result of freezing of the water left in the water jackets, or other contributory causes, by the

oxy-acetylene welding process. Alternatively, there is an electrolytic process* which has given satisfactory results; this has the advantage of requiring no heating of the cylinder block, with consequent risk of distortion.

In the oxy-acetylene welding method it is possible not only to effect fully satisfactory repairs to cracks in external walls of water jacket, but also to weld on complete patches of cast iron and even to weld in new cylinder barrels.

Small cracks in the outer walls of water jackets can often be repaired satisfactorily, by first drilling a series of continuous holes (Fig. 117) along and just beyond each end

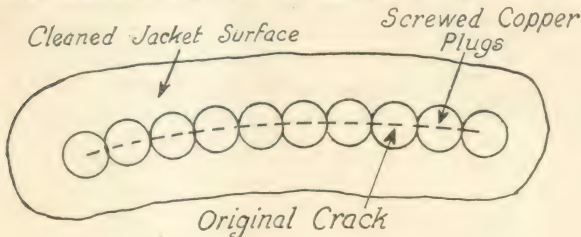


FIG. 117

of the crack, tapping these holes so as to give a taper thread and then screwing in corresponding tapered screwed copper plugs. These are then filed down smoothly to the surface of the jacket, cleaning the cast iron for about $\frac{1}{4}$ in. all around the studs. The stud heads and the cleaned iron surface is then tinned and given a thick solder coating, afterwards painting over with a cellulose black paint or enamel.

When cylinder blocks have to be repaired by welding it is important that they should be preheated in a muffle to just below a dull red heat before welding in order to avoid heat distortion effects that may otherwise leave the metal in a state of stress or cause cooling cracks. After welding they should again be heated to a dull red and allowed to cool very slowly in the muffle by shutting off the heat supply in the muffle. This process relieves the cylinder blocks of internal stresses.

* *Production and Engineering Bulletin.* Ministry of Supply Publication. Sept. 1944.

Cylinder blocks are often repaired by the bronze welding method, of which the Sifbronze process* is a good example. The surfaces to be repaired are first "tinned" with bronze welding rod after vee-ing adjacent edges. The cylinder blocks are preheated and flux-coated bronze welding rods are employed. The finished blocks are annealed in the manner previously described.

The advantage of the bronze welding method is that an appreciably lower welding temperature is used, so that there is less risk of distortion; moreover, the welding process is a simpler one than that of iron welding. The oxy-acetylene blowpipe is employed for bronze welding.

In regard to the welding temperature this is about 900° C. for bronze welding rods as compared with 1550° C. for iron welding. The preheating temperature is also much lower than for iron, the usual temperature being 450° C.

* Suffolk Iron Foundry Ltd., Stowmarket.

CHAPTER VII

CONNECTING-RODS AND CRANKSHAFT

WHEN the connecting-rod has been removed from the crankshaft and the piston disconnected, it should be cleaned thoroughly and then examined for the following faults, namely: (1) *wear in small-end bush*; (2) *wear or scoring of big-end whitmetal*; (3) *alinement of small- and big-end bearings*. The oil holes should also be checked for cleanliness.

The Small-end Bush. This is usually a gunmetal or bronze bush, which is made a press fit in the connecting-rod

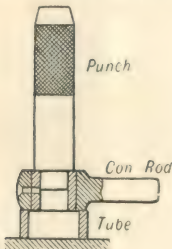


FIG. 118

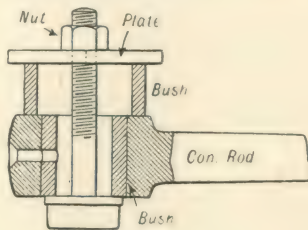


FIG. 119

hole. It has an oil hole on the upper side with grooves inside the hole for distributing the oil. In some instances, where the connecting-rod is rifle drilled for lubrication, the oil hole is on the lower side of the bush.

The gudgeon pin should be checked with a micrometer for wear. If any wear is found, a new pin should be fitted; otherwise, if the bush is worn to any measurable extent, a new one should be employed. In this case it will often be necessary to fit a new gudgeon pin as well.

The bush may be removed by drifting it out over a hard wood or metal block having a slightly larger hole than the outside diameter of the bush (Fig. 118). Alternatively, a nut and bolt device of the type shown in Fig. 119 can be used for extracting the bush.

The new bush, which may be a makers' spare part or one specially machined in the lathe, should be of good quality gunmetal or phosphor-bronze, and machined so as to be just a free running fit on the pin and a force fit in the connecting-rod hole.

When the bush is inserted with a hand press, or by means of a nut and bolt device (somewhat similar to that

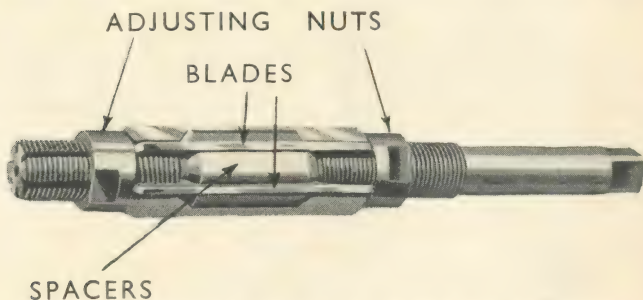


FIG. 120. EXPANDING SIX BLADE REAMER FOR PRECISION REAMING OF GUDGEON PIN HOLES IN SMALL END AND PISTON BOSSES

shown in Fig. 119), it will be found that the pin hole becomes smaller by about $\frac{1}{8}$ - to 1-thousandth inch, owing to contraction occurring during the insertion process. The bush should then be reamed or honed out, using special tools made for the purpose. A skilful mechanic will be able to lap or scrape the bearing until it is a good bearing fit on the pin. As the bush has only to rock on its pin the fit can be very slightly on the tight side, but nevertheless free enough to allow of the usual oil film between the two surfaces.

In an emergency a slightly worn bush can be used again if it is first tinned on the outside and then forced into the connecting-rod hole so as to contract it sufficiently to take up the wear.

In cases where an *oversize gudgeon pin* is available as a spare part, the makers provide a special reamer for the small-end bush and piston bosses, such that the pin will be a satisfactory fit in these holes. If a spare bush is used,

it is important to see that its oil hole is in proper alinement with the hole in the rod end.

When inserting a new bush it is not advisable to hammer it in—even with a copper drift—as the metal around the edges may distort and give an erroneous idea of the pin fit. Always use some form of press or screw device for inserting the bush.

Fixed Gudgeon Pins. In cases where the pin is clamped securely to the small end of the connecting-rod (Fig. 10) the fit of the pin in the piston bosses should be checked. If any signs of wear are found, a new oversize pin will be needed, the small-end hole and piston bosses being reamed or honed out to suit. The latter machining operations should be done with the connecting-rod secured in place, between the piston bosses.

Big-end Bearings. Before attempting to take up the wear in big-end whitmetal bearings, or to fit new half bearings, the condition of the crank pin should be ascertained by measurement with a micrometer. After lengthy service the crank pin will be found to have worn slightly oval—to the extent of 0.001 to 0.003 in., according to circumstances.

In such cases it is essential to true up the crank pin before fitting the big-end bearing.

The crank pin, in an emergency, can be trued by hand if a certain amount of skill is exercised, the metal on the unworn sides being carefully removed with emery cloth or a fine file followed by application of the emery cloth. Ordinary lapping methods will not true up an oval crank pin, however. The better method in cases where the crankshaft cannot be trued up in a proper grinding machine is to use one of the specially designed crank pin tools of the single or multiple cutter class. Typical examples of such tools are the Bradbury, Ammco, K.B., and Arnott ones.

The Bradbury tool (Fig. 121) has three accurately alined locating surfaces and a single cutter. The cutting diameter is adjustable by means of the fine-threaded screws and nuts shown; it is claimed that a crank journal can be trued to within $\frac{1}{4}$ -thousandth inch with this tool.

The Ammco tool (Fig. 122) operates upon a similar

principle, using two plane surfaces at right angles to locate the shaft and cutter. The cutting diameter is varied by means of the large milled head shown.

The Arnott tool illustrated in its two models, *A* and *B* in Fig. 123, has been designed to true up the journals of

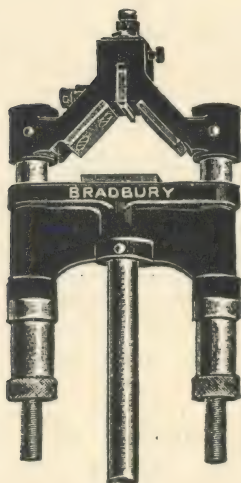


FIG. 121. BRADBURY
CRANK PIN TOOL

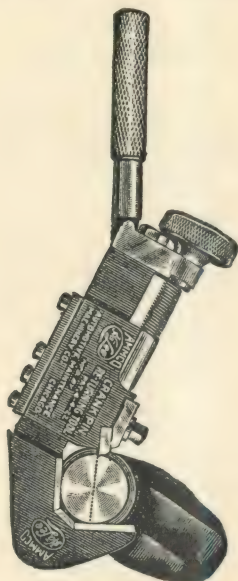


FIG. 122. THE AMMCO
TOOL

crankshafts both expeditiously and accurately. They embody a special cutting tool and a Vee-shaped guide to ensure that the tool edge is accurately aligned with the journal to be lined up. A fine adjustment is provided so that the cut can be regulated easily to within half a thousandth inch; the method of adjustment is one of the patented features of the tool.

Referring to diagram *A*, the tool-holder and adjustment block have stud positions which move in the slotted body; when the securing nuts are slackened the tool-holder can

be moved towards the shaft journal until the tool just touches it. The adjustment block with its screw device is then brought up to touch the tool block and both members are locked in the slot by means of their nuts. The cut or feed is applied by means of the handle on the right-hand side and a movement of one-third of a complete turn gives a forward feed of one-thousandth inch.

The *B* model represents a simpler form than the model

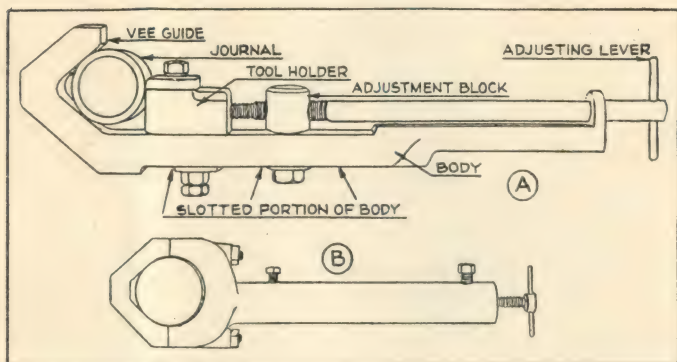


FIG. 123. THE ARNOTT CRANKPIN TOOLS

A; it is neater in appearance and the actuating mechanism is enclosed.

Another model of this tool is designed for attachment to the lathe bed or crank case sump studs or bolts so that it becomes a self-contained crankshaft truing machine.

Crankshaft tools of the types described are operated by rotating them bodily around the journals, using light cuts and an ample supply of a suitable cutting lubricant.

In many instances these tools can be used on crankshafts in place in their crankcases, but the work is greatly expedited if the crankshafts are taken to the bench for the purpose.

After truing with a cutter-type tool the journals can be given a high degree of surface finish by lapping them with a pair of half-bearings of copper or lead, using a mixture of fine carborundum powder and oil.

BUILDING UP WORN CRANK JOURNALS

Crank pins or main journals that have worn down or have become oval may be built up by the electro-deposition method, using nickel or chromium deposits. They are made

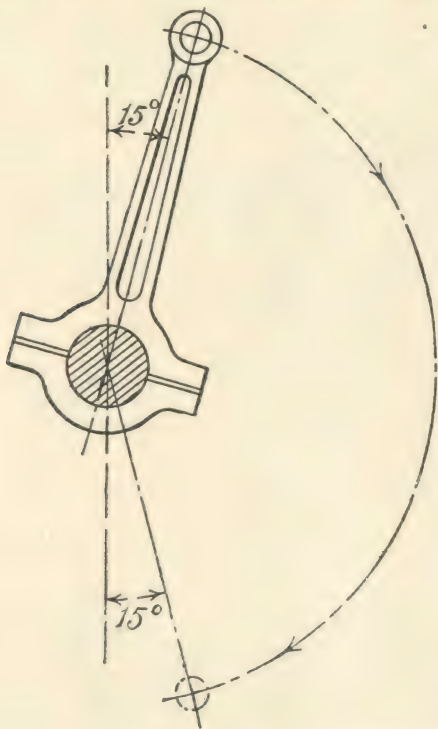


FIG. 124. METHOD OF TESTING FIT OF BIG-END BEARING

slightly oversize and are then reduced to the standard diameters by a subsequent grinding process. When chromium is used the journals last very much longer than hardened alloy steel surfaces. Worn surfaces can also be built up by a metal spraying process which has been developed by The British Oxygen Company Ltd., using an

oxy-acetylene flame for melting the metal feeder rod and compressed air for spraying it on to the shaft.

TAKING UP WEAR IN BIG-END BEARINGS

If, upon examination, the big-end whitemetal is found to be in a satisfactory condition, free from mat effects, scores or cracks, thin places, etc., the cleaned bearing should be fitted to its appropriate crank pin and, after tightening the nuts down hard, tested for radial and end play.

When a connecting-rod bearing is a satisfactory fit on its pin, the connecting-rod, if placed nearly vertical, should just be able to descend to within 15° of its lowest position (Fig.

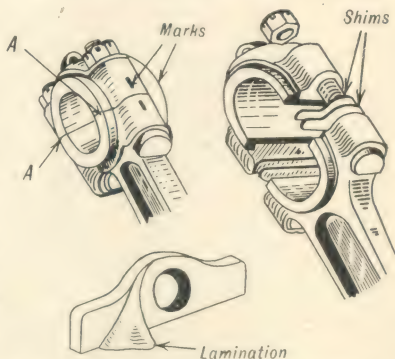


FIG. 125. BIG-END BEARING DETAILS.

124) in virtue of its own weight. The greatest amount of bearing wear occurs at about 45° to 60° from the top dead centre position in the direction of rotation, so that the connecting rod should be tested on its pin in this position.

The amount of sideways rocking movement that can be given to the connecting-rod, at its small end, is another indication of the degree of wear sustained; the amount permissible is about $\frac{1}{8}$ in. at the small end.

BEARING AND CRANK PIN CLEARANCES

The best check on the big-end bearing is that of measurement with an inside micrometer, and comparison with the outside diameter of the crank pin. The usual bearing clearance when correctly fitted and bedded down is about 0.002 to 0.004 in. dependent upon the size of crank pin. For small car engines the clearance is usually from 0.0015 to 0.002 in.; for large engines it is from 0.0035 to 0.0045 in.

The side clearance varies from 0.005 to 0.008 in. according to the size of engine.

If the measured clearances exceed from two to three

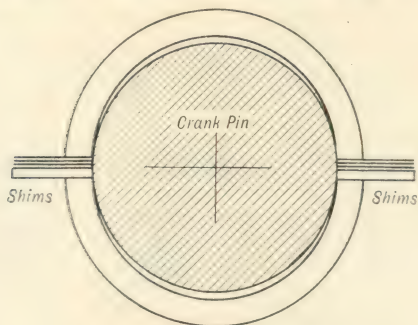


FIG. 126

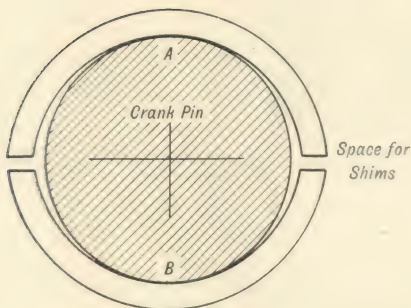


FIG. 127

(Clearances shown exaggerated)

times the values given, the wear should be taken up, or new bearings fitted.

Taking Out Shims. To take up the wear in white-metal big-end bearings, the surfaces of which are in good condition, one or more of the packing liners, known as shims, should be removed from each side of the bearing.

When a bearing wears the appearance (Fig. 126) is that of an oval or ellipse with its longest axis in the direction of

the connecting-rod's length. The effect of removing the appropriate thickness of shims (usually from 0.002 to 0.005 in.) is to reduce the vertical axis AB of the oval so that it becomes slightly less than the diameter of the pin (Fig. 127). Then, the whitemetal at A and B must be

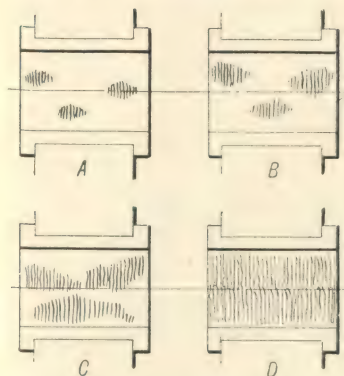


FIG. 128. STAGES IN SCRAPING DOWN A BEARING

scraped away until the pin bears evenly over the whole surface of the bearing.

FITTING BEARINGS

The method used in bedding whitemetal bearings is to give the pin or journal a very light smear with Prussian blue oil paint, or with a paste made from red lead and oil. The two halves of the bearing are then tightened down just sufficiently to enable the rod to be turned around the pin. Upon separating the two bearing halves and examining their surfaces a number of dark spots or patches will be found; these correspond with the high spots or "hillocks" on the whitemetal.

The process of fitting the bearing consists in scraping down these high spots with a half-round scraper, and testing again on the marked pin until the spots, or broader patches, are evenly distributed all over the surface, when the bearing cap is tightly bolted down to the rod end. The final scraping should be a very light one, but no attempt

should be made to polish the bearing with emery cloth or the results will be fatal.

Fig. 128 shows the appearance of a big-end or main bearing during different stages of its scraping in. At *A* the high spots are denoted by the dark areas. When the first scraping operation occurs, these areas become progressively larger as at *B* and *C* until finally the bearing marks extend evenly all over the two halves as at *D*.

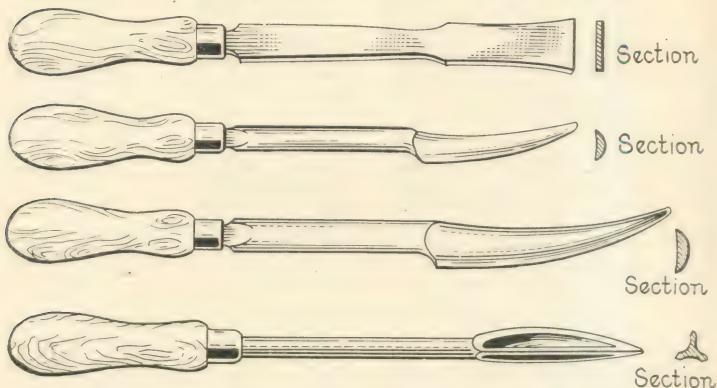


FIG. 129. TYPES OF SCRAPERS USED FOR BEARINGS

Before scraping in shell-type bearings see that these are properly bedded down into their caps and rod ends respectively.

A method that gives good results is to fit the bearing, so that when the connecting-rod cap bolts are fully tightened so that the castle nuts are in the correct positions for their split-pin holes, the rod is a slightly tight fit on the pin. The connecting-rod cap and the opposite side of the rod are then given a few light taps with a hammer, when the rod will become free by the correct amount.

After having fitted the bearings they should be taken apart and the oil grooves cleaned, or deepened by scraping. Further, the whitmetal should be reduced for a short distance on either side of the flat face edges, as shown by the "cut away" part in Fig. 130. The object of this recess is to provide, on the lowest pressure areas of the bearing, a

trap for any solid matter that may find its way into the bearing with the oil supply. The oil holes should be cleaned through and well rounded off.

Full Ring Connecting-rod Bearings. The engines of certain modern cars are fitted with full-ring whitemetal bearings of the butted type, i.e. the two halves of the bearing completely encircle the connecting-rod, without leaving a gap and without the use of packing shims.

It is very important with this type of bearing *not to*

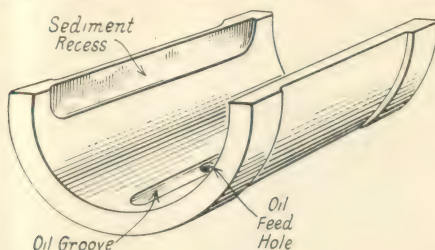


FIG. 130. TYPICAL WHITEMETAL HALF BEARING

attempt to take up wear by the process of filing the caps, as this will be detrimental and render the connecting-rod useless for future bearing replacement.

The bearings are made by a method which renders it unnecessary for the caps or rods to be touched by a file or scraper. If, therefore, the clearances become excessive—as a result of prolonged usage—the rods should be remetalled by an expert firm or the rods exchanged for new or reconditioned ones at the makers' agents.

The working clearances with *Morris big-end bearings* are rather greater than was previously the accepted practice, so that in the unlubricated state it is possible to rock the connecting-rods by a small amount. When the oil film is present between the bearing and crank pin, however, the clearance is correct. The connecting-rod, in the dry bearing condition, should therefore fall freely on its crank pin when the big-end bolts are fully tightened. It is important that when a connecting-rod has been removed, it should be reassembled with *the little end clamp bolt on the off-side of the engine.*

Whitemetalling Big-end Bearings. Cracked or badly worn bearings, if no spare half-bearings are available, can be remetalled as follows. First prepare a steel tube core of a diameter a little smaller than the crank pin. Fix this securely to a steel plate, and then fit the core members corresponding to the packing pieces between the two halves of the bearing (Fig. 131).

These core members can be fixed into slots cut into the

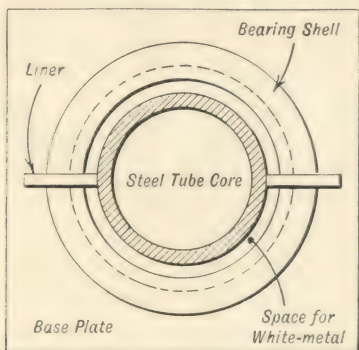


FIG. 131. REMETALLING A BEARING

tubular core. The faces of the core members are given a coating of a wash made from red clay and water or graphite and water, to prevent the whitemetal from adhering to the core.

The surfaces of the connecting-rod and its cap, upon which the whitemetal is to be cast, should be properly tinned. It is necessary first to clean these surfaces in a hot caustic soda bath, followed by a washing in hot water. Tinning is done with a good grade of tinman's solder, using a suitable flux such as killed spirits (zinc chloride), Fluxite, or Hoyt powder flux. Another excellent method is to use the self-fluxing and tinning compounds, known as Soldo or Soltic; these will give satisfactory results on dirty surfaces also.

Having tinned the surfaces and mounted the rod and cap correctly with the core or cores previously described, one should warm up the whole assembly with a blow-lamp

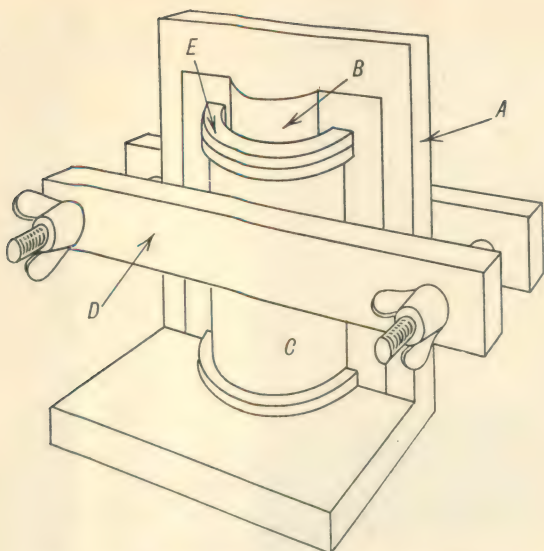


FIG. 132. MOULD FOR HALF BEARINGS (HOYT)

A = Vertical plate *C* = Bearing
B = Inner liner *D* = Clamping device
E = Flange

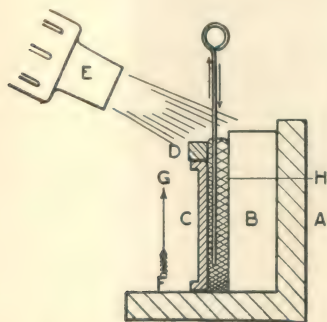


FIG. 133. METHOD OF WHITEMETALLING A BEARING

A = Metal base *D* = Top ring
B = Core *E* = Blow lamp
C = Bearing shell *FG* = Direction of filling
H = Molten metal

flame. The molten whitemetal, after removing the dross, is then poured slowly into the mould, filling the bearing as high as possible. Immediately the bearing is full, take a piece of iron wire and dip it continuously in and out of the molten metal, all round, and at the same time prevent the metal at the top from solidifying by means of the blow-lamp flame; this process is termed "venting" or eliminating air and gas bubbles (Fig. 133).

Finally, allow the bearing to cool down as quickly as

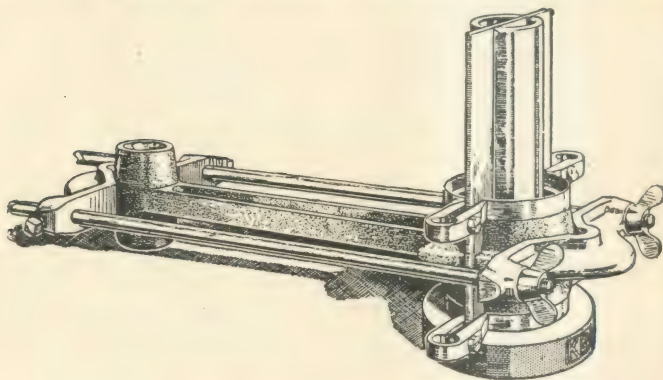


FIG. 134. BIG-END BEARING MOULD (K.B.)

possible, with an air blast played on the bottom of the bearing; a wet rag or cloth may be used for this purpose.

Any possible sources of whitemetal leakages when pouring may be stopped up with a paste made of asbestos meal and water, or with clay, or putty. These should be well dried before the metal is poured into the bearing.

Special whitemetalling moulds are now available for motor car engine bearings, typical examples being shown in Figs. 134 and 135; with the aid of these moulds the operation of remetalling is greatly simplified.

A method of ensuring sound whitemetal linings of even density, free from blowholes and other defects is that of the Forwell* remetalling method, the principle of which is

* Cuthbert Machine Tools Ltd., Guildford.

illustrated in Fig. 136, showing the connecting rod portion of the bearing, with the metal core in position and the molten

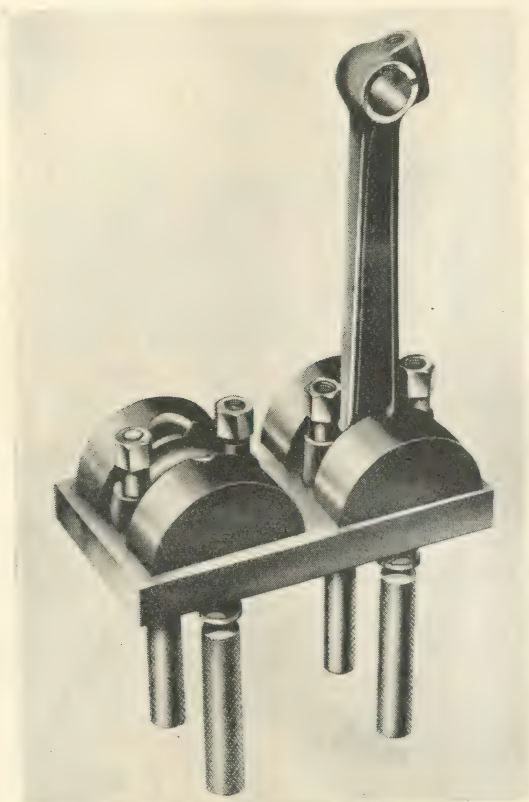


FIG. 135. MOULD FOR TOP AND BOTTOM BIG-END BEARINGS

metal poured in. The core has a funnel-like cavity *A* into which the metal is poured. It flows through the orifice *B* and up into the spaces *C* between the core and connecting-rod. The core is kept at about the same temperature as the molten metal; thus, the metal which cools at the point

of contact with the bearing or connecting rod and causes a shrinkage of this metal in the recess is replaced with the flow of liquid metal from the well of the core.

For the same design of connecting rod about 15 rods can be tinned and re-lined within the hour, no puddling or venting being necessary. The complete remetalling outfit

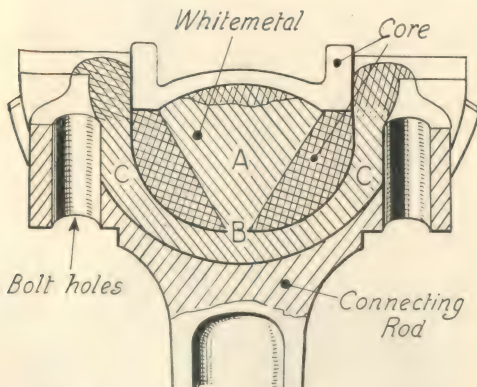


FIG. 136. THE FORWELL REMETALLING METHOD

includes a welded steel stand, two gas-heated metal melting pots, a bellows and blowpipe and sundry accessories.

Boring Out the New Bearings. After remetalling a connecting-rod big-end bearing, the latter must be bored out to fit the crank pin. The usual method is, first to insert the packing pieces and shims between the two parts, then bolt up the bearing tightly, and clamp the rod down, in a special jig or fixture designed for the purpose, on the lathe carriage. The jig has a pair of vee-blocks for locating a pin which is pushed through the small-end bush; this ensures that the axis of the big-end bearing is in a line with that of the small-end and at right angles to the longitudinal axis of the rod.

A cutter bar (Fig. 137) is employed to bore out the big-end bearing, the bar being rotated, while the lathe carriage is fed slowly along the lathe bed. Special cutters are employed for radiusing and facing the ends of the bearing.

The cutters used are generally of the tungsten-carbide tipped steel variety, which retain their cutting edges over very long periods. Two cutters are used for boring; one for roughing and the other for fine finishing.

The recommended turning speed for whitemetal with

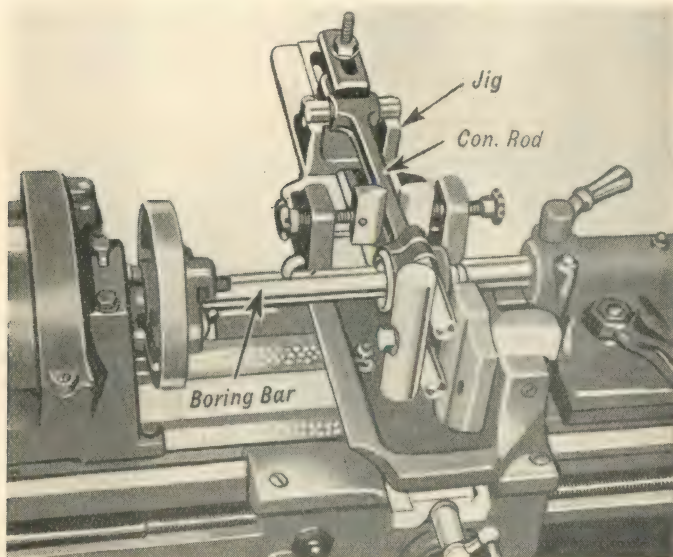


FIG. 137. METHOD OF BORING BIG-END BEARINGS

high-speed tool steel is 350 to 500 ft. per min.; for tungsten-carbide from 700 to 1000 ft. per min. When an appreciable number of whitemetal or lead-bronze bearings have to be machined the use of a diamond cutting tool is to be recommended. Special connecting-rod and main bearing boring tools now on the market enable these bearings to be accurately rebored. Fig. 138 shows the K.B. tool designed for connecting-rod big-end bearings. It has a bracket for holding the rod, accurate location of the small-end and big-end bearings being ensured by a small-end fixture and the rod clamp. The boring bar is operated by the handle shown, an automatic feed being provided. A special

micrometer is attached for setting the radius of the cutter, with an accuracy to within 0.001 in. of the required size. The tool, which is clamped in the vice, is adjustable for rods of different centres (from 7 to 15 in.), and one model will deal also with the main bearings.

Connecting Rod Boring Machines. Special machines are now available for boring out whitemetalled big-end bearings accurately and quickly. These machines are of both the hand- and electric motor-operated patterns and will deal

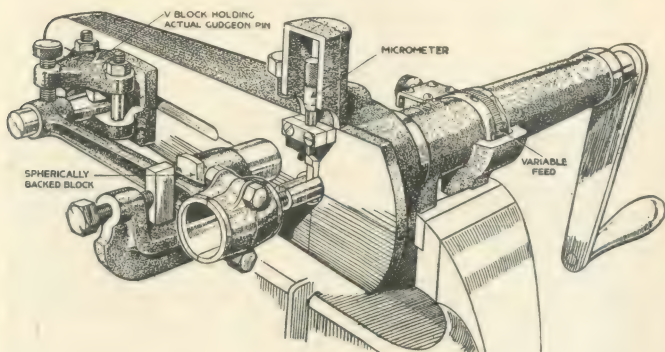


FIG. 138. THE K.B. BORING TOOL

either with single rods or repetition work; in the latter case adjustable connecting rod locating and clamping jigs are provided, so that it is a relatively simple operation to insert and accurately locate each rod by adjusting one or two screws or bolts only. Fig. 139 illustrates the Cuthbert* hand-operated machine, which will deal with connecting rods from $5\frac{1}{2}$ in. to $12\frac{1}{2}$ in. length (between centres). The rod, as shown, is located below by its own gudgeon pin in a vee-block secured in a slotted guide member. Above it is located by means of three pointed screws carried in an inverted U-shaped bracket which can be adjusted and clamped on four guide bars.

The boring head carries a tungsten carbide cutter. It

* See footnote on page 136.

has two substantial bearings and is fed through the connecting rod big-end bearing, automatically, by means of a screw-and-nut device.

The machine is supplied with a micrometer for setting the cutter diameter and it can also be used for facing,

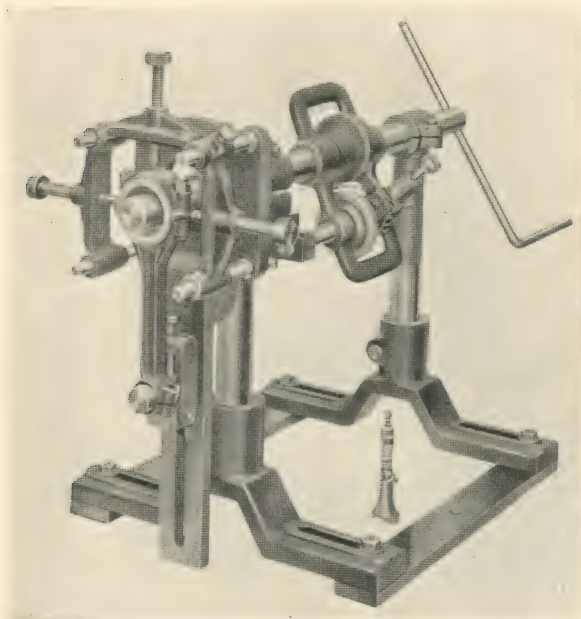


FIG. 139. THE CUTHBERT HAND-OPERATED CONNECTING ROD BORING MACHINE

chamfering and radiusing the ends of the bearing, after the latter had been bored.

A power-driven machine is also made by the same firm for boring the big-end bearings. This provides three cutting speeds, namely, 600, 900 and 1400 r.p.m. The latter speed is suitable for diamond-boring tools and an automatic feed of 0.002 in. per revolution of the tool gives a very fine surface finish.

CHECKING CONNECTING-RODS FOR ALINEMENT

When the connecting-rod is removed from its piston and crank pin, after cleaning and reassembling the big-end bearing, it should be checked for the following possible

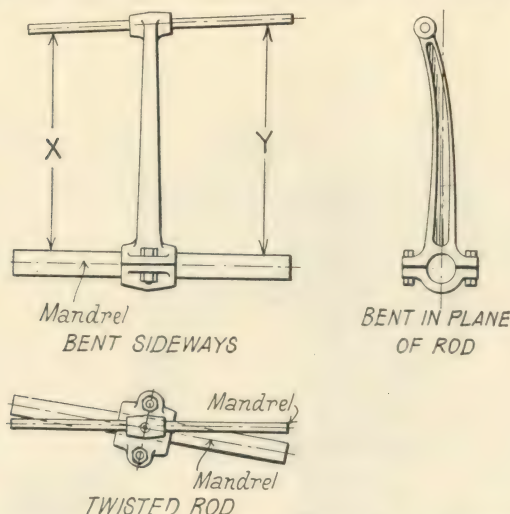


FIG. 140. CHECKING CONNECTING-ROD FOR ALINEMENT

faults (Fig. 140): (1) Bending so that the axes of the small- and big-end bearings become inclined, instead of parallel, and (2) twisting of the rod.

These faults can be readily detected by placing straight rods or shafts of about 10 in. length in the bearing holes so as to give good push fits in these holes. If, now, measurements be taken between the two ends and the distances *X* and *Y* are found to be unequal, this indicates that the rod is bent.

The presence of any twisting effect can be revealed by sighting down from the small-end; if the two bars are not in line, but are inclined as shown in Fig. 140, then the rod is twisted.

Special connecting-rod alinement devices are now available for checking rods for bending or twisting. Typical

examples of such aliners include the G.E., Harvey Frost, and Millennium. The principle of most of these devices is that of locating the big-end bearing by means of a mandrel and then checking the alinement of a rod which is a push fit in the small-end by means of machined surfaces provided for the purpose. In some cases the piston is assembled on the rod and the alinement of its face checked against a machined face at right angles to the big-end mandrel. The G.E. aliner has an adjustable machined block against which the gudgeon pin or a small-end mandrel is checked; the block is held against the pin by means of a spring.

Fig. 142 illustrates a typical connecting-rod alinement testing jig*, which is particularly useful where a number of rods has to be checked in the routine servicing of engines.

In the upper illustration the connecting rod is shown mounted on an expanding-type mandrel having precision machined cylindrical end pieces which rest in vee-blocks on the jig. The gudgeon pin is shown inserted in the small-end bearing and any twisting effect on the rod is indicated by the fact that one side of the gudgeon pin does not rest on the parallel guides but rises above its guide when the other side rests on its guide. Any side-bending effect is shown by measuring the distances of the small-end bush faces from the inside vertical faces of the parallel guides. These distances in the case of an unbent rod should, of course, be equal. The lower illustration shows the test made for alinement of the piston with the big end journal. If not in alinement the feeler gauge will give different readings at the top and bottom ends, when used on *both sides* of the piston; the tapered design of the piston is thus allowed for in this method of testing. In

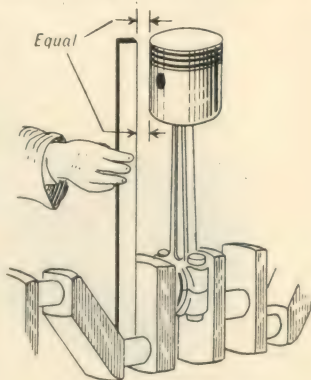


FIG. 141. CHECKING
CONNECTING ROD
ALINEMENT

* Boneham and Turner Ltd., Beeston, Notts.

this set-up the parallel faces of the guides take the place of the cylinder barrel and all measurements made from these

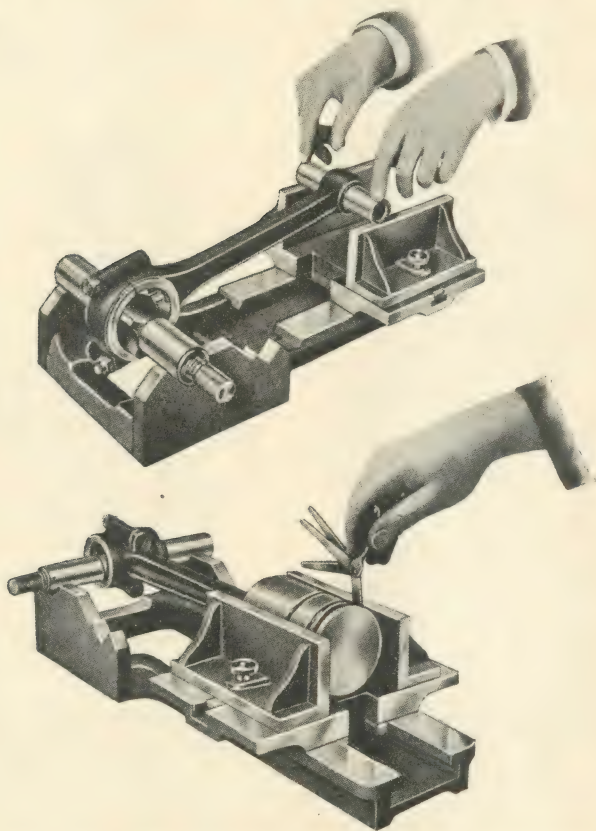


FIG. 142. THE B. AND T. CONNECTING ROD ALINEMENT TESTING JIG

faces are similar to those that would be obtained in the cylinder barrel itself. Both tapered and oval-ground pistons can be checked with this jig.

Connecting-rods found to be bent may be straightened

in a hand press by placing blocks near the ends of the rods and applying pressure in the centre. Special connecting-rod straightening tools are now available, a typical example, known as the "G.E.," being illustrated in Fig. 143. This provides two projections which bear against the concave side of the rod and a hand screw for applying pressure to the centre of the convex side in order to straighten it.

When straightening a connecting-rod care must be exercised in order that the metal is not indented or injured in any manner; the use of softer metal packing pieces at the

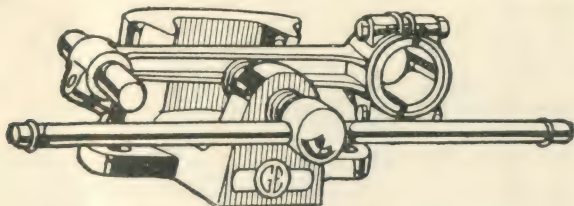


FIG. 143. CONNECTING ROD STRAIGHTENER

bending spots will obviate the risk of damage. Connecting-rods should therefore not be straightened in a vice unless similar precautions are taken to avoid damage of the metal, for the latter is heavily stressed in the engine when it is operating.

Tightening the Big-end Bolts. When reassembling a big-end bearing after scraping it in, it will often be found that the connecting-rod nuts cannot be screwed up sufficiently for the split-pin holes to align with the castle-nut slots. Since these nuts must be very tight, they should certainly not be slacked back to allow the split pins to enter. The correct procedure in such cases is to file down the bearing face of the nut, a little at a time, until the split pin can be inserted after the nut has been well tightened down; care is necessary to ensure filing of the nut dead square with its sides.

THE CRANKSHAFT

Except after very long periods of service it is seldom necessary to attend to the crankshaft. If, however, the

main bearings exhibit any signs of journal wear or too much end clearance; or if oil leaks out of the bearings, as shown by persistent low oil pressure readings on the gauge, then the crankshaft should be removed for examination.

The flywheel must be disconnected and the timing gear pinion removed—in most instances; after taking off the bearing caps the crankshaft can then be taken out. Care is necessary when disconnecting the oil pipes from the bearings not to damage these.

After appreciable periods of service, exceeding about 30,000 to 40,000 miles an examination of the crankshaft main and big-end journals will often reveal score marks and out-of-roundness. The crankshaft should first be degreased and cleaned and then the diameters of the journals measured carefully with an outside micrometer, vernier callipers or one of the special crankshaft measuring gauges, such as the Ames, Mercer, Surbito or Starrett ones. Which-

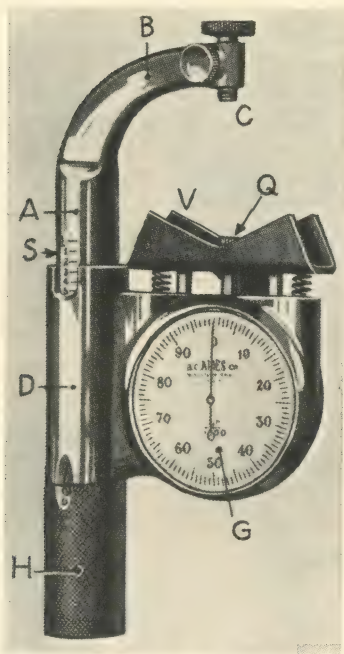


FIG. 144. THE AMES CRANKSHAFT GAUGE

ever type of gauge is used it should enable diameters to be measured to within one-half thousandth inch.

Fig. 144 illustrates the Ames crankshaft gauge, which will measure both taper and out-of-roundness to within the limits just stated. It consists of a stem *A* having a scale *S* graduated in $\frac{1}{10}$ in. divisions and a bent arm *B* at the upper end housing an adjustable contact member *C*. Another unit consisting of a bracket *D*, which can slide on the

cylindrical scale portion of the former, carries the dial measuring gauge G and a narrow sliding sheetmetal vee-block V , provided with light springs to assist in alining it on the journal to be measured. A knurled handle H is provided to screw the member A up or down for the purpose of measuring the journal. The measuring point Q of the dial gauge is at the centre of the vee-block and makes contact on a diameter, opposite to C . The dial gauge scale is divided into 100 equal divisions, each one of which represents $\frac{1}{1000}$ in. By estimating between the division spaces it is possible to read to $\frac{1}{4}$ -thousandth inch.

In regard to the *nature of the wear on crankpins*, as the load or thrust of the connecting rod is greatest between the T.D.C. position and 90° of crank angle maximum, wear occurs on the contact surface of the crankpin in this position. There is also an increase wear effect experienced between the B.D.C. position of the crankpin and the top of the succeeding compression stroke; this also occurs on the upper surface of the crankpin.

Crankshaft Regrinding Sizes. When it is found necessary to retrue or regrind the crankshaft journals on account of scored surfaces or ovality it is important to arrange for the diameters of the reground journals to suit the dimensions of the replacement bearings, which are now usually of the split shell type.

These replacement bearings are supplied by the engine manufacturers in the following definite *undersize* dimensions, namely, 0.010, 0.020, 0.030, 0.040 and 0.060 in. The *tolerances* allowed on the crankpins and main journals when regrinding to these undersizes are 0.0005 in. Thus, in the case of the Austin commercial vehicle engine for an undersize of 0.010 in. the minimum and maximum permissible dimensions of the crankpin are 2.1148 in. and 2.1153 in. respectively; and for the main journals 2.4690 in. and 2.4695 in. respectively. The corresponding undersize bearing shells have then the correct clearances.

It should be mentioned that, provided the crankpin and main bearings are reground to the undersize dimensions previously stated, the replacement bearings will fit correctly without any scraping-in or fitting.

Crankpin and Main Journal Bearing Clearances.

According to the type of engine the clearance between the crank-pin and big-end bearing should be from 0.001 to 0.002 in.; in some instances clearances of 0.003 in. are used. The same clearances also apply to the main bearings.

The endwise clearance or "float" along the crankpin lies between 0.007 and 0.012 in. and for the main bearings from 0.002 to 0.004 in.

When lead-bronze bearings are fitted, as in the case of certain high grade car and high speed Diesel engines,

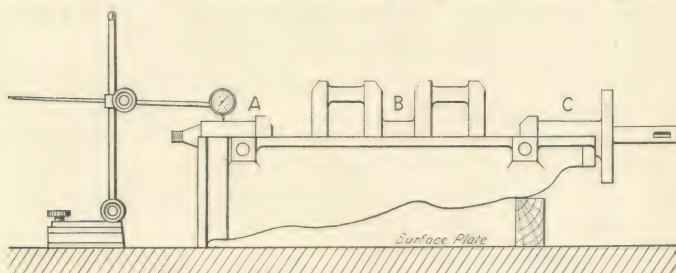


FIG. 145. TESTING THE CRANKSHAFT

greater bearing clearances must be employed for the main and big-end bearings. These are usually from 0.004 to 0.006 in. with end clearances of 0.008 in.

Testing Crankshaft for Straightness. After measuring the crankpins and journals prior to regrinding it is important to test the crankshaft for straightness, since in certain designs—notably where there is not a separate main bearing between each pair of cranks—there is a tendency for the crankshaft to become slightly bent.

To check the crankshaft it can be mounted between the centres of a lathe—if the original machining centres have been left in the ends—and, with the aid of a scriber block fitted with a dial gauge, used on the bed of the lathe, the concentricity of the main bearings can be checked as it is rotated slowly by hand to within $\frac{1}{1000}$ in.

Alternatively, if the crankshaft is mounted in its own main bearings as shown in Fig. 145, and the crankcase or cylinder block is packed up on a large surface plate so that the end journals A and C are exactly at the same

distance from the surface plate, as measured with a dial gauge, it can readily be ascertained whether the intermediate journals, such as *B*, are true with the end bearings by checking with the dial gauge at *B*. The crankshaft should be rotated slowly during this test.

The crankshaft can also be checked for straightness in

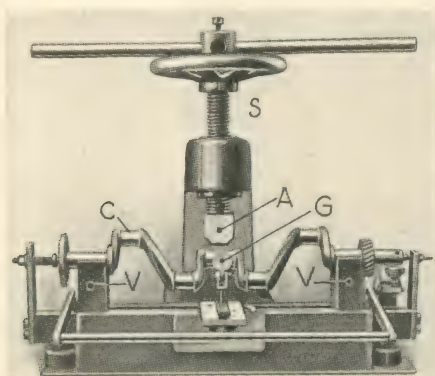


FIG. 146. COMBINED STRAIGHTENING PRESS AND GAUGE

the press illustrated in Fig. 146 with the aid of the dial gauge *G*.

Straightening the Crankshaft. The crankshaft if found to be slightly bent can be straightened in an ordinary arbor or screw press, but special presses such as the one shown in Fig. 146 are now available for automobile servicing establishments. The crankshaft *C* is mounted on massive vee-blocks *V*, and a powerful screw press *S* is used to apply the straightening effort by means of the anvil *A*. The degree of straightness is checked during the operation by the dial gauge *G*, which reads to within $\frac{1}{1000}$ in. The crankshaft should be rotated in the vee-blocks when taking readings, to check for concentricity.

Building Up Worn Journals. Instead of regrinding worn crankshaft journals to "undersize" dimensions and fitting undersize bearings the journals can be built up with steel, nickel, or chromium, and then reground to their original

new dimensions, so that standard bearings can be fitted. There is thus no loss of crankshaft strength due to reduction in journal diameter by grinding, whilst the bearing surfaces are not reduced in area.

There are two principal methods of building up journals, namely, (1) by electrodeposition and (2) by metal spraying.

(1) *Electrodeposition*. In this much-used method, after degreasing and cleaning by chemical means, i.e. "pickling" the surfaces to be built up, the other surfaces which are not to be plated are painted over with a protective paint, sold commercially for the purpose, and the crankshaft then immersed in the electrolyte of a plating vat, the crankshaft being connected to the negative electrode of the current supply.

Originally pure iron was used for building up purposes, but the modern practice is to employ either *nickel* or *chromium*.

When nickel is used, the deposited metal is much harder than the ordinary nickel in the cast or annealed condition. It is also very strong; tensile strengths up to 35 tons per sq. in. being obtained. The deposit adheres to the steel so well that there is no risk of its separation under working conditions. It can be machined or ground to size and polished to a high degree so that it forms an excellent bearing surface.

Chromium coatings are much harder and give considerably longer wear than either the original steel surfaces or nickel deposited ones. Actually the chromium is glass hard and can only be finished by grinding.

There is no theoretical limit to the thickness of the coatings for either nickel or chromium. Thin deposits of 0.005 in. can be given by suitable control of the plating operation to a tolerance of plus or minus 0.001 in.

New crankshafts for high output, e.g. racing car engines, are sometimes provided with chromium-plated journals (main and crankpin), whilst the contours of the cams on camshafts are treated in like manner greatly to increase their wear-resistance.

(2) *Metal Spraying*. In this method any fusible metal or alloy, e.g. alloy steel, can be sprayed on to the properly prepared surfaces of the crankshaft and will adhere very

firmly. Any desired thickness of metal can be deposited. The metal (steel alloy) to be deposited is provided in the form of wire of small diameter arranged on a freely-rotating drum from whence it is led to a special design of spraying pistol. The latter is provided with three different gaseous supplies through separate flexible pipe connections, namely, oxygen, acetylene (or coal gas), and compressed air. The oxygen and acetylene supplies go to a blowpipe nozzle in the usual manner of the oxy-acetylene welding blowpipe. The compressed air is

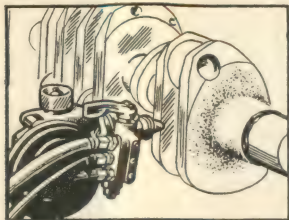


FIG. 147. METAL-SPRAYING PROCESS

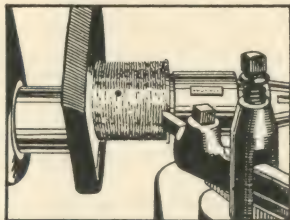


FIG. 148. PREPARING THE SHAFT FOR SPRAYING

led to the nozzle through a separate passage. It is also used to rotate an air turbine, which through a reduction gear system in the pistol feeds the alloy steel wire at a uniform (but hand-variable) rate through the pistol. As the wire emerges into the nozzle portion it is melted by the oxy-acetylene flame and is then projected in the form of extremely small droplets on to the surface to be coated (Fig. 147). The formation on the surface is in the nature of very small "saucer-shaped" particles which adhere to the surface and each other.

In this method it is essential to roughen the journal before spraying (Fig. 148). This is usually effected by using a knurling tool or cutting a fine-pitched screw thread. There is thus some weakening in the strength of the journal, although in the case of a new method, which employs a special oxy-acetylene torch to deposit fine particles on the shaft, a sufficiently rough surface is provided for the sprayed metal and there is no such loss.

An advantage of this metal spraying method is that it

does not affect any previous heat-treatment results, as the surface deposited upon is relatively cold. The fact that alloy steels can be sprayed and the induction hardening method subsequently employed is another point in its favour.

It should here be mentioned that specialist firms such as Fescol Ltd. (electrodeposition) and Metallization Ltd. (metal spraying) now undertake this work on a commercial basis.

Examination of Engine Parts for Cracks. An important procedure that should be undertaken in routine reconditioning of engines (and other stressed members of the chassis) is the inspection of the working surfaces for fatigue or stress cracks. If these are allowed to persist the components will eventually break down in service. Crankshafts and camshafts, gears and gear shafts are particular examples of components that are liable to develop surface cracks.

A simple method for detecting such cracks, if not too minute, is as follows.

The cleaned component is first heated to a moderate temperature, e.g. the boiling point of water, and is then immersed in a paraffin bath or brushed over with paraffin. It is then cleaned with a cloth so as to get rid of all surplus paraffin and is brushed over with a thin coating of whiting and water, allowing this to dry. After a few hours the presence of any cracks is revealed by the seeping out of paraffin from these cracks, causing the whiting to discolour.

Commercial methods of crack detection, for which special plant is now available, e.g. that of the Equipment and Engineering Co. Ltd., London, are based upon placing the cleaned component in a magnetic field, with the magnetic flux running either longitudinally or peripherally, and then painting the surfaces under examination with "magnetic ink," i.e. extremely fine soft iron particles in a liquid solution. The "ink" is usually black or red in colour and it adheres only to the cracks in the component, revealing these in fine detail. It will show hair cracks too fine to be detected by the naked eye.

Another method, used for non-magnetic parts, e.g. aluminium and magnesium is the *fluorescent one*. The

component is first cleaned thoroughly and then immersed in a special liquid containing particles of salts possessing strong fluorescent properties. After removal from the bath the liquid is wiped off the surface and the component illuminated by an ultra-violet lamp, when any cracks present are at once revealed by clearly defined luminous green lines. For a full account of the above and other crack detection methods the footnote reference* should be consulted.

Crankshaft Repairs by Welding. With the great improvements in modern welding methods and technique it is now possible for specialist firms to repair fractured crankshafts by the electric arc welding process and to guarantee satisfactory results. Usually, it is necessary to straighten the broken crankshaft after welding. The cause of fracture—which may be due to worn bearings or to misalignment of these—should be ascertained before the repaired and re-ground shaft is reassembled in the engine. It is, of course, not possible to obtain the original grain structure or flow lines by welding repair, so that a slight loss of mechanical strength results; usually, however, the factor of safety for the crankshaft is high enough to cover this slight weakening effect.

Crankshafts repaired by welding should be re-balanced before replacement in the engine.

Crankshaft Regrinding Machines. Where numbers of crankshafts have to be reground in servicing workshops it is best to employ a special grinding machine designed especially for this purpose.

There is now a range of such machines available, including the simpler models, such as the Wincona "Intheblok" model,† which will regrind the crankpins without removing the crankshaft from the engine in place in the car, to the more elaborate machine shop Churchill grinding machine, referred to later.

The Intheblok machine when used on the engine in the car chassis employs an electric motor which drives the crankshaft through the jacked-up rear wheel of the car and the transmission. For the main bearings it can be

* *Engineering Materials, Volume 3, Chapter 14.* Non-Destructive Methods of Testing. A. W. Judge. (Pitman.)

† E. P. Barrus Ltd., London.

mounted on a centre lathe, with the aid of a special bracket fitting.

The Sunnen portable crankshaft grinder will regrind crankshafts on or off the engine. It is provided with a micrometer feed hand wheel for varying the grinding wheel cut and a shaft follower or steady bearing opposite the

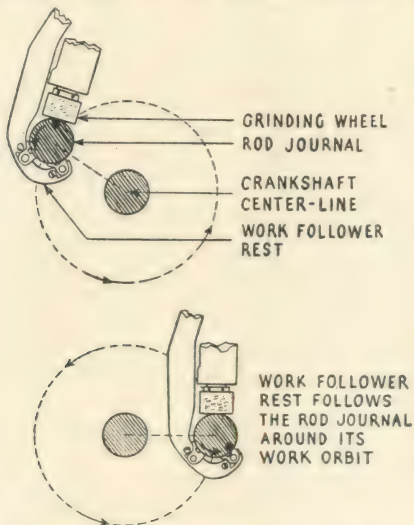


FIG. 149. SHOWING PRINCIPLE OF THE SUNNEN GRINDER

small grinding wheel; the latter grinds on its end surfaces and not on the cylindrical faces as is usually the case (Fig. 149).

The Churchill machine, designed especially for regrinding automobile engine crankshafts (Fig. 150) and available in four models for lengths of crankshafts up to 36, 50, 72 and 84 in. respectively, covers all the needs of garage and repair shops and all types of crankshafts from those of light car engines to heavy vehicle Diesel engines. It has quickly adjustable crank throw blocks, live work-head and tailstock for crankpins and dead centres for the main journals; an *electric indicator for balancing crankshafts*; special design of "Hydrauto" grinding wheel spindle

bearing adjustment with Nitalloy hardened grinding wheel spindle; work drive by belt—no gearing being employed; a patented *swarf separator* which ensures a high degree of finish on the work; *diamond tool wheel truing unit* and “finger tip” control of the table traverse. The latter is of the automatic *hydraulic feed type*, now used instead of

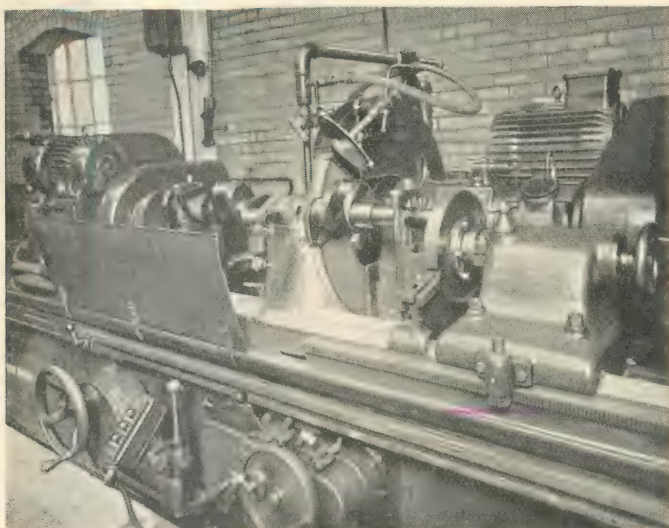


FIG. 150. THE CHURCHILL CRANKSHAFT GRINDING MACHINE

worm and nut traverse on most modern precision grinding machines.

Fig. 151 illustrates the method of providing for the alteration of the work grinding axis or “throw” to bring the crankpins into the correct centre of rotation for regrinding purposes.

Provision is made for grinding to within 0.0001 in., if required. Four different work speeds are arranged for in these machines.

A useful fitting on this machine is a large diameter adjustable mirror which can be tilted or moved so as to illuminate the portion of the work being ground.

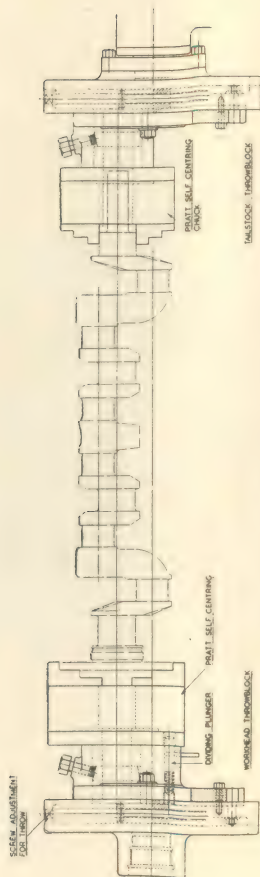


FIG. 151. CRANK THROW ADJUSTMENT DEVICE

FITTING MAIN BEARINGS

The fitting of new main bearings or the scraping in of worn ones is, perhaps, one of the most difficult operations for the motor mechanic, unless he is fortunate to possess a main bearing boring machine, such as the Cuthbert or Buma models; these machines have automatic locating or alining devices and are provided with boring bars fitted with high-speed cutters, one for each bearing. The bars are rotated by means of handles or a geared motor and the feed is applied by means of a screw and nut device, such that the rotation of the bar feeds the cutters forward. All of the main bearings can be bored at once, there being a separate cutter for each.

When wear effects in main bearings have to be taken up, the same procedure is followed as for big-end bearings, the crankshaft being rubbed lightly with marking and rotated by hand in the bearings so as to show up the high spots; the latter are then scraped down. It is best to scrape in the half-bearings in the crankcase member first, to ensure that the crankshaft beds down evenly on all of these bearings. When the bearing areas are uniform and there are no high spots, the caps can be fitted and their white-metal surfaces scraped down, progressively, until they bed evenly on the journals. The object when fitting these caps is to ensure that after they are bolted down tightly, the bearings will not only bear evenly on the journals but will also have the correct running clearances. To achieve this object the fitting, testing, and taking off of the bearing caps must be repeated a number of times until the desired fit is obtained.

The procedure recommended for Morris engines which are not fitted with the later "shimless" type main bearings is that the centre bearing be adjusted first, and then the front and rear ones. Shims will be found under each bearing cap and these should be removed as required. If necessary, each bearing should be scraped until a correct marking is shown when in position, with each cap perfectly tight. Do not attempt to file the bearings or caps.

When all three crankshaft bearings have been correctly adjusted, it should be just possible to turn the crankshaft

round by means of the starting handle. Care should, however, be taken to ensure that this tightness is not caused by one bearing in particular.

Where "shimless" bearings are employed these are of the full-ring, butted type and are manufactured to such close limits that they are absolutely interchangeable. Should

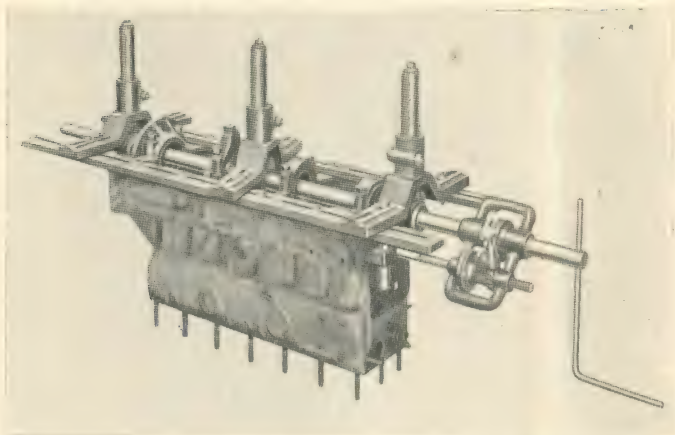


FIG. 152. CUTHBERT MAIN BEARING BORING MACHINE

any trouble be experienced through shortage of lubrication, etc., damaged bearings can be replaced quickly at small cost; they should not be interfered with in any way other than to replace them, provided the crankshaft is not damaged.

On no account should the bearing cap be machined or filed.

It is important, when fitting main bearings, to see that the crankshaft has the proper degree of end clearance; this varies in different engines from 0.006 to 0.010 in.; the journal clearances range from 0.003 to 0.006 in. It is also necessary to ensure that the ends of the bearings are radiused sufficiently to clear the corresponding radii on the crank journals; otherwise the correct fit of the bearings may be interfered with.

Some manufacturers recommend fitting the main bearings so that the crankshaft rotates with a slight amount of "tightness." The bearings are then well lubricated and the crankshaft is rotated for several hours at a speed of about 300 r.p.m., by means of an electric motor or pulley and belt. Afterwards it will be found that the crankshaft is freer in its bearings. It should, however, be taken out of its bearings and any high spots found on the latter lightly scraped away.

Engines which have had their main bearings renewed or refitted should be operated at low speeds for the first few hours to enable the bedding down process to be completed.

Main Bearing Boring Machines. In modern automobile engine reconditioning workshops, the use of hand- or machine-operated main bearing boring machines not only saves a considerable amount of time but also ensures a high degree of accuracy in the alinement of the bearings; further, an excellent finish can be given to the bearing surfaces.

A typical example of a hand-operated machine designed for this purpose is shown in Fig. 152.* It will accommodate a wide range of engine sizes and covers bearing diameters of $1\frac{1}{2}$ in. to $3\frac{1}{4}$ in. The machine is located on the reversed cylinder block (carrying the main bearing) by the front and rear main bearings. It consists of a bed in which the cylinder block is mounted, a boring bar for traversing the main bearings with a length of 5 ft. to 6 ft. 6 in., according to the type of engine. Two cast iron formes are turned to fit the front and rear main bearings. The block is then mounted upside down on the cross members of the machine and secured by draw-bolts and cross-pieces. Then, a clamping piece is bolted to each crankcase flange. These pieces carry the bridge pieces which, with the pillars and swivel-heads, form the boring bar steadies. After the boring bar has been passed through the formes in the front and rear bearings the two end steadies are threaded on to it.

As the boring bar is rotated it is fed through the bearings automatically, the feed being reversible. The boring bar is designed to take boring tools at 5 in. intervals, the

* Cuthbert Machine Tools Ltd., Guildford, Surrey.

tools being locked in place by Allen grub screws. Facing of the bearings can also be carried out with this machine, which is also supplied as a power-driven model, fitted with a $\frac{1}{2}$ h.p. electric motor and primary belt drive. A special

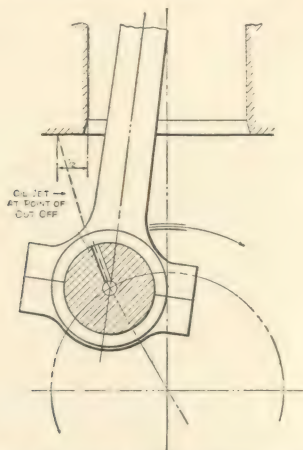


FIG. 153. OIL JET FOR LUBRICATING CYLINDER WALLS

micrometer is supplied and with its aid accuracy of dimensions to a tolerance of 0.00025 in. can be attained.

Arranging for Oil Jet on Cylinder Walls. In oil pressure lubrication, the oil is fed to the hollow or drilled crankshaft and eventually finds its way out through holes drilled through the crank pins and journals to the bearings. In the case of the crank pin holes, if these are drilled in the position shown in Fig. 153 and corresponding holes are made through the connecting-rod metal, a jet of oil will be directed, once every revolution on to the cylinder walls, to lubricate the latter.

CHAPTER VIII

THE TIMING GEAR

ALTHOUGH there are many makes of engine still in service with spur gear drives to the camshaft, the majority of modern engines employ roller chain drives of the plain or self-adjusting pattern.

When backlash occurs with spur gear train drives, very little can be done to remedy this. In some cases it may be found that there is a certain amount of wear on the intermediate gear pins and bearings; this can be eliminated by fitting new bushes, if the pins are not worn appreciably, or by new pins and bushes.

The backlash due to tooth wear can only be rectified by fitting new gear wheels, however.

Chain-driven timing gears are of the double or treble roller chain type, the latter being used on commercial vehicles.

In many cases—particularly with the small and medium class of cars—the same roller chain drives the camshaft and ignition distributor shaft while the dynamo and fan are belt-driven from the external crankshaft pulley.

Tension in the timing chain is sometimes adjusted by means of an eccentric bush on an idler sprocket, or—when the dynamo is chain-driven—on the dynamo drive shaft bearing bush.

In other cases, notably on typical overhead camshaft models, there is a flat spring tensioner for taking up any backlash in the chain.

The Armstrong-Siddeley chain drive to the camshaft and dynamo (Fig. 154) is adjusted by unslackening two bolts holding the dynamo flange to the timing casing and then rocking the dynamo unit, so as to move it away from the engine, for tightening the chain. Should the timing chain be removed for any purpose it will be necessary to retime the valves—and sometimes the ignition also.

Fig. 154 also shows the method of replacing the double roller timing chain on the Armstrong-Siddeley engine. To do

this it is necessary to turn the crankshaft and camshaft by hand until the line on the flange of the former and the O on the face of the latter are opposite and adjacent to one another. Thread the chain over the crankshaft wheel (Fig.

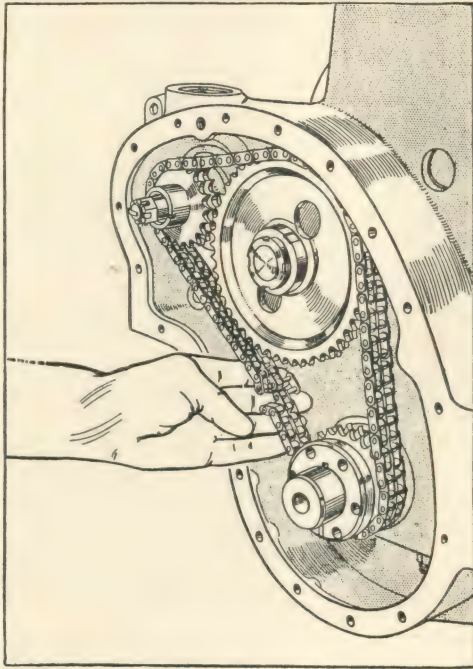


FIG. 154. ADJUSTING THE TIMING CHAIN

154) and, taking care that the camshaft wheel does not move, fit the chain round it from the top. The joint in the chain should be placed at the most convenient point, so that the detachable link can be fitted from the back.

If no means are provided for taking up the effects of chain stretch and wear, and the backlash becomes excessive, a new chain should be fitted. Before doing so, however, the sprocket teeth should be examined for signs of excessive wear (Fig. 155). Any lack of symmetry in the shape

of the teeth is an indication of such wear. In such a case the only remedy is to fit new sprockets and a new chain.

Chains should not be allowed to run in the stretched condition since, apart from noisy operation, the valve timing will be affected. The *usual effect of chain stretch* is to cause *all of the valves to open too late* and, of course, to close too late.

The usual life of a good make of roller chain for timing drive purposes varies from 40,000 to 50,000 miles.

When an automatic chain tensioning device is fitted—as shown in Fig. 156—any slackness that may develop in the chain is taken up by means of a spring which forces the idler sprocket in a direction at right angles to the chain. A ratchet and pawl device prevents the sprocket from moving back.

There are two kinds of automatic tensioner sprockets, namely, one having the idler sprocket mounted on ball-bearings, the spindle being subjected to a light spring pressure so as to keep the chain tight; the sprocket then slides in a straight-sided guide (Fig. 156) and has a ratchet device to hold it. The other automatic tensioner (Fig. 157) employs an eccentric bearing for the idler sprocket and a clock spring tensioning device fitted with a non-return ratchet and pawl to prevent it from moving back so as to slacken the chain.

When replacing the timing chain with an automatic tensioner of this type the chain is fed from the camshaft sprocket over the top of the crankshaft sprocket and joined up to the other end with the slack end of the chain embracing the idler sprocket. Now, fit the eccentric into the chain-tensioner sprocket and turn the eccentric in an anti-clockwise direction as far as it will go and replace the ratchet. It is, of course, necessary to retime the engine when the chain has been removed.

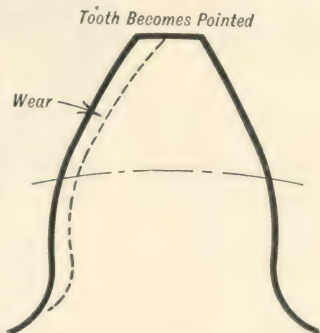


FIG. 155. CHAIN SPROCKET
TOOTH WEAR

To tension the chain correctly, turn the chain-tensioner eccentric as far as it will go in an anti-clockwise direction, replace the ratchet with its slotted cover plate outwards,

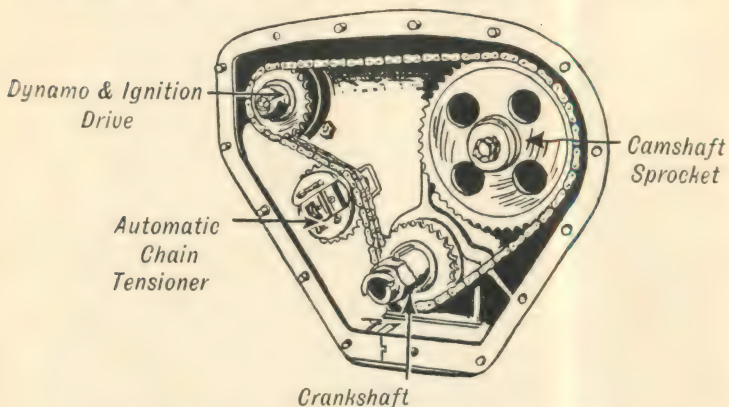


FIG. 156. TYPICAL TIMING CHAIN ARRANGEMENT

and engage the pin in the eccentric with the slot in the ratchet. Engage the tongue in the centre of the spring with the slot in the chain-tensioner spindle and *wind up three and a quarter turns* in a clockwise direction. Then lock the end into one of the four slots provided for it in the outer edge of the eccentric.

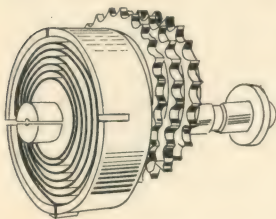


FIG. 157. SPIRAL SPRING
AUTOMATIC CHAIN
TENSIONER

Timing the Valves.* When the timing gears or chain drive have been disconnected, it is necessary to reset the camshaft in its correct position relatively to the crankshaft so that the valve timing will be correct.

It is only necessary, with single camshaft engines, to set the opening point of one valve, when timing the engine; if this is correctly set all the other valves will also be correctly timed—since

* See also page 22.

all the cams operating these valves are solid with the camshaft.

When the timing gears are marked and the flywheel rim has the top dead centre position of No. 1 piston marked, the timing of the valves is a simple matter, since it is only

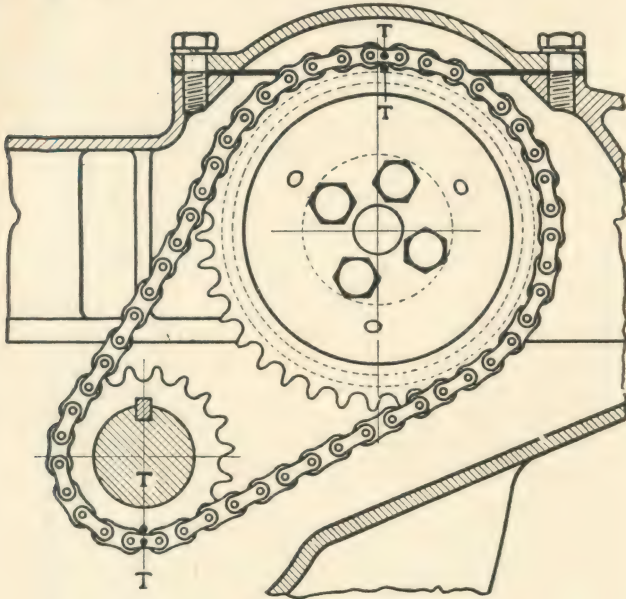


FIG. 158. MORRIS ENGINE TIMING MARKS

necessary to set No. 1 piston on its T.D.C. and the marks on the gear-wheel (or sprocket) against their timing marks, when the intermediate drive gears or the timing chain can be replaced; neither the crankshaft nor the camshaft should be disturbed in doing this.

Fig. 158 illustrates one of the Morris engine timing gear arrangements, using a roller chain drive from the engine sprocket to the camshaft sprocket—which has twice the number of teeth of the former.

It will be observed that one tooth on each sprocket is marked with the letter "T." The chain is provided with

two bright links in different places along its length. To time the valves correctly it is necessary to rotate the camshaft independently of the crankshaft to a position such that the bright links on the chain can be slipped over the sprocket teeth having the mark "T."

Before timing the valves it is necessary to set the valve stem clearances to the valves recommended by the engine manufacturers.

In the case of certain modern engines having specially designed cams for silent operation with relatively big clearances, e.g. 0.017 to 0.020 in., it is always advisable to use the timing chain sprocket or gear wheel markings to set the valve timing.

Timing Unmarked Engines. If the valve timing gears are not marked it will be necessary to obtain a copy of the engine manufacturer's valve timing diagram, which is generally given in the typical form shown in Fig. 15.

The top dead centre of the engine can readily be determined by watching the piston, or feeling it through the sparking plug hole with a rod or wire. The flywheel rim, if not already marked with a line, should be given a chisel cut or line of centre punch dots, and a corresponding line made opposite this line on the clutch or crank casing; sometimes a metal pointer can be fitted for this purpose.

The distances around the flywheel rim corresponding to the angular positions of the opening or closing of the valves can be estimated by the method described on page 25, so that with the aid of a steel tape one can measure and mark on the flywheel the distance corresponding to, say, the angle at which the inlet valve of No. 1 cylinder begins to open.

The flywheel is first set on its No. 1 cylinder T.D.C. position and the camshaft drive disconnected. The flywheel is then moved through the measured inlet valve opening distance before or after the T.D.C. position; if on the latter there is, of course, no need to move the flywheel.

Next, the camshaft is turned in its proper direction of rotation until the No. 1 cylinder inlet valve commences to open. The timing gear drive to the camshaft is then

coupled up, when the valve timing for all cylinders will be correct.

It is important to set the valve tappet clearances correctly before timing the valves as too much or insufficient clearance will alter the valve timing.

Accurate Method of Timing Valves and Ignition Units.

In connection with the timing of valves and also ignition units, it is generally necessary to be able to ascertain the exact moments of opening of the valve or of the contact breaker points. The writer has devised a method which is simple to employ and gives a very accurate result. It consists in the case of valve timing of first setting the valve stem clearance to the manufacturer's recommended value, with the aid of a feeler gauge. The inlet valve clearance is adjusted until the appropriate feeler blade will just slide between the tappet (or rocker end) and the valve stem; being neither too tight nor too free. Once the clearance is set to the manufacturer's figure and locked, a feeler gauge of $\frac{1}{1000}$ in. greater thickness than the correct value is pushed between the valve stem end and the operating tappet or rocker arm. This will be found to require a distinct effort, the feeler blade then being a tight sliding fit.

After the piston (or flywheel rim marking) has been set to the correct position corresponding to the inlet valve opening angle, with the camshaft drive disconnected, the camshaft is rotated very slowly by hand, in its proper direction of rotation. The feeler blade is held in one hand by means of its holder and given a slight pull as though to move it from between the valve stem end and operating gear. Immediately the camshaft reaches the correct position for opening the inlet valve, the feeler blade will become locked and cannot then be pulled out. Thus, as soon as the blade commences to lock the camshaft will be in the correct position corresponding to the inlet valve opening. The camshaft drive can then be replaced.

For *ignition timing purposes* a blade of, say, $\frac{2}{1000}$ in. is inserted between the contacts and the moment of opening or separation of the points will at once be evident by the easing of the feeler blade as it is subjected to a constant light pull, whilst the contact breaker cam drive is rotated slowly.

Timing O.H.V. Camshaft Engines. On most overhead camshaft engines the camshafts are chain-driven from the crankshaft, the sprockets on the camshafts being bolted to flanged members on the ends of the shafts. The bolt holes in the sprocket members are usually slotted in a tangential

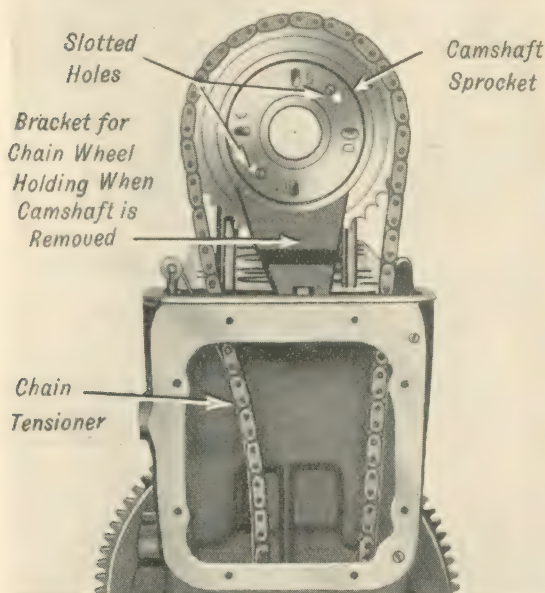


FIG. 159. OVERHEAD VALVE TIMING METHOD

direction to enable the valve timing to be reset should chain stretch occur.

Fig. 159 illustrates a typical arrangement. The roller chain has an automatic spring tensioner and the upper (and larger) chain sprocket is bolted to the camshaft flange by means of bolts and nuts, the heads of the bolts being located by a plate having soft metal tabs.

The sprocket member is slotted as previously described. The edge of the flange has an engraved line, which is

brought opposite a fixed pointer on the rocker shaft end bracket. This gives the No. 1 inlet valve opening position. It is then necessary only to place No. 1 piston on its T.D.C. as determined by a mark on the flywheel rim, and to set the mark on the camshaft flange against the index. The bolts can then be passed through the upper sprocket and the nuts tightened up. The chain and sprocket are replaced together on the camshaft flange boss. When the sprocket is taken off—as for engine decarbonizing—it can be rested upon a special bracket on the cylinder block casting so that there is no need to disturb the chain position.

In some cases motor-car engines are *timed with the exhaust valves fully open*, marks being made on their flywheels to show the crankshaft position corresponding to the exhaust valves being wide open. It is considered more accurate in such cases to observe this position of maximum lift, rather than the gradual opening position of the valve.

Before retiming the valves of any engine, it is important, as previously mentioned, to set the valve stem clearances to their correct values, since the clearances affect the valve timing.

When the camshaft is gear-driven from the crankshaft it will usually be found, on examination, that the corresponding teeth of the gears are marked, there being a line or punch mark on one tooth and two similar marks on the two teeth with which the former meshes in its correct position.

CHAPTER IX

THE RADIATOR AND COOLING SYSTEM

AFTER a car has been in service for some appreciable time the cooling system will require a certain amount of attention in order to maintain its proper cooling efficiency.

About once every 3000 miles the tap should be opened at the base of the radiator and the water drained out; a note should be made of the colour of the drained water. If appreciably dirty or rusty in appearance, the whole cooling system should be flushed out.

To do this, remove the radiator filler cap and insert the nozzle of a water hose into the filling orifice. Leave the radiator drain tap open; then turn on the mains supply and regulate this so that there is a constant flow through the system but no overflow at the top. The water should be allowed to flow through until the emergent stream is quite clear; when this is the case, turn off the water supply and allow the surplus to drain out through the radiator tap.

Radiator Expansion Chamber. The loss of water by evaporation is prevented in the case of the Austin radiator by an expansion chamber. When the cooling water expands it rises and fills the chamber (Fig. 160) while the displaced air escapes from a small overflow pipe connecting the top of the chamber with the bottom of the filler plug well. If any further expansion occurs water flows along the overflow pipe to the filler plug well and when the engine cools this water is drawn back into the radiator through the overflow pipe, so that no water is lost. *The capacity of the 10 h.p. cooling system (which employs thermo-siphon circulation) is 2 gallons, 3 pints.*

Deposits in Radiators. Hard deposits from water will impair the cooling efficiency of the system with a subsequent tendency for the water to boil under normal running conditions, owing to the clogging up of the radiator water spaces.

Such deposits resemble those in domestic water pipes and kettles and may, to some extent, be eliminated by

filling the cooling system with a strong solution of washing soda (calcium carbonate) and water. It is best to use this solution hot, afterwards running the engine until the solution nearly reaches the boiling-point. Then allow the system to stand for about twenty-four hours and afterwards drain the solution out, finishing with a good flushing through with cold water as previously described.

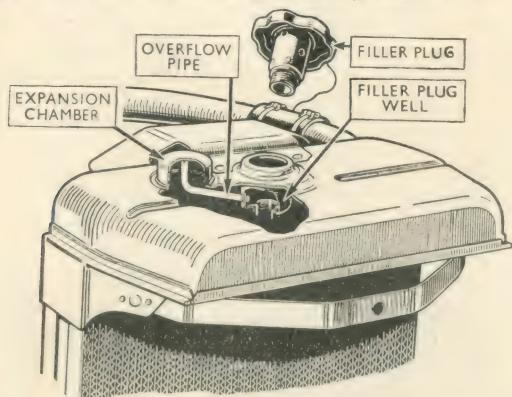


FIG. 160. AUSTIN RADIATOR EXPANSION CHAMBER

Some manufacturers recommend the reverse flushing of radiators that have been treated with sodium carbonate solution, to remove the dislodged deposits. This method, however, involves the use of compressed air equipment.

If caustic soda solution is used, the process is shortened. It is necessary only to run the engine, with radiator cap screwed down tightly, for about twenty minutes, but the solution should not be allowed to boil. Afterwards stop the engine, drain, and finally flush through with clean water.

A special rust and corrosion inhibitor is available for neutralizing the action of any soda that may be left in the cooling system. This is of particular importance in the case of aluminium cylinder head engines since *soda solutions attack aluminium and its alloys*; for this reason the method of cleaning with sodium carbonate solution is not recommended since the period required would be detrimental to any aluminium parts.

Leaks in Radiators. The presence of ordinary leakages can be detected by examination, but small leaks are often difficult to trace. The soldered joints around the hose

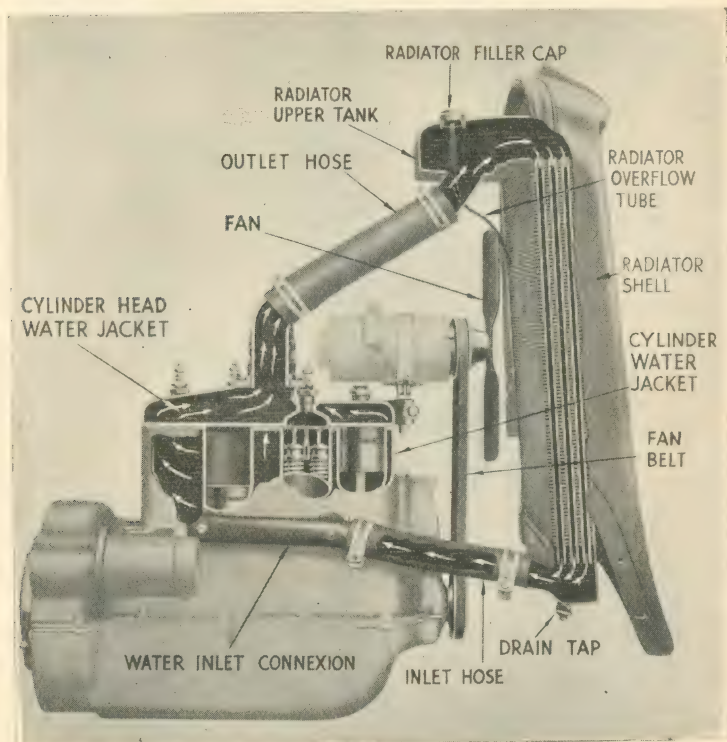


FIG. 161. THE COOLING SYSTEM

connexion pipes, the holding-down lugs, and the upper and lower tanks of the radiator should be cleaned and then examined for such leaks. The radiator fins should also be gone over carefully.

If the leak cannot be detected in this manner, the radiator should be removed from the chassis and its inlet and outlet pipe connexions plugged with cloth-covered wooden plugs.

Another wooden plug should be inserted in the filler cap and a bicycle valve let into this so that air can be pumped into the radiator with a hand pump. If now the radiator be immersed in a tank of water (Fig. 162) the leak can at once be detected by the air bubbles which issue from it. Do not use too much air pressure, i.e. above about 5 lb. per sq. in., or the radiator may become strained.

Small leakages can be repaired with plumbers' solder, using killed spirits (zinc chloride) or a proprietary flux such

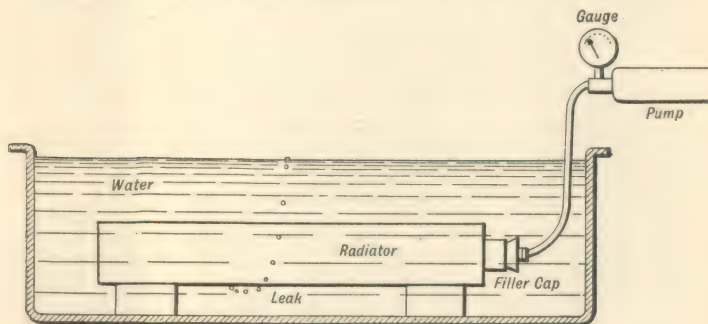


FIG. 162. METHOD OF TESTING RADIATOR.

as Fluxite or Baker's Soldering Fluid. Do not use a blow-lamp for this purpose; a large copper bit is the most satisfactory appliance to employ.

The repair of seriously damaged radiators is, however, usually outside the scope of the average motor mechanic, so that this work should be done by a specialist firm, such as Messrs. Barimars Ltd.

The use of *special compositions to stop leakages* in radiators is strongly deprecated, since these tend to clog up the fine water cooling passages of the radiator.

Filling Radiators. When filling radiators after flushing use only soft water such as filtered rain water. If the domestic water supply has a water-softener fitted, the softened water should invariably be used. See that all water poured into the radiator is properly strained so that no solid matter can find its way into the radiator water spaces.

Cooling Systems with Thermostats. When a thermostat

is embodied in the cooling system it is important to ascertain, when filling, that this does not cause an air lock.

The modern thermostat is of the bellows pattern; the axial movement of the bellows is arranged to open and close a valve in the cooling system. When cold, the bellows is contracted and the valve closed, thus shutting off the cylinder water jacket from the radiator. When the cylinder water is hot the bellows expands and the valve is opened,

so that the cooling water can circulate freely through the water jackets and radiator.

In the case of the thermostat shown in Fig. 163, the bellows B is connected by a linkage to the shaft of a butterfly valve A in the upper water outlet pipe to the radiator.

The modern thermostat seldom, if ever, requires any maintenance attention.

When a car has been stored for a long period *the thermostat may not operate, owing to corrosion.* If the unsatisfactory behaviour of the cooling system indicates *thermostat trouble* the thermostat should be removed and placed in a

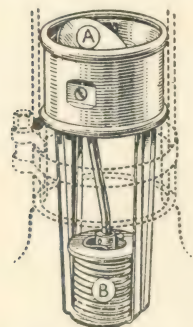


FIG. 163. BUTTERFLY VALVE TYPE OF THERMOSTAT (AUSTIN)

vessel of hot water the valve being then examined to ascertain whether it opens satisfactorily; if it does not it may require attention or adjustment. If, then, it fails to operate, a new unit is indicated.

When filling the radiator after the water has been emptied out, allow a few minutes for the air to escape through the thermostat valve before topping up.

Testing Radiators. After a radiator has been repaired, or if it is suspected of being partly clogged with water sedimentary deposits, it may be tested by what is known as the "Flow Test Method." In this case the rate of flow of water through the radiator is compared with that of a new radiator of the same type. It is usual to provide a tank of about 10 gallons capacity and arrange this above the radiator so that there is a definite head of water which is the same for each test. The upper inlet of the radiator is

connected by a suitable length of hose-pipe to the outlet cock of the test tank, and the outlet of radiator is led to a drain or waste gully. The time taken for 10 gallons of water to flow can then be measured in each case.

In this connexion the ordinary medium car type radiator

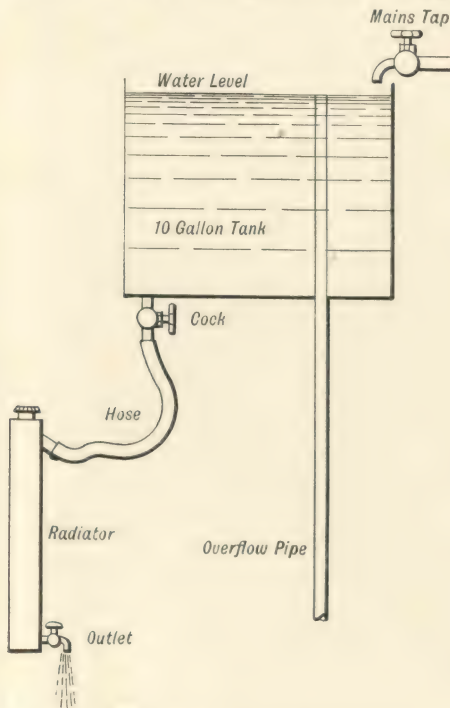


FIG. 164. FLOW TEST OF RADIATOR

requires from forty to sixty seconds for 10 gallons of water to flow under a 4 ft. head.

Radiators should be tested, after repair work, for tightness and strength by plugging up the inlet and outlet orifices with rubber plugs or by soldering disks of brass over the ends. The filler cap should be tightly screwed down, using a rubber washer to make the joint.

A hole should be made in one of the sealing plugs or the filler cap and a rubber connexion made to a suitable inlet nozzle. Air at a pressure of 3 to 6 lb. per sq. in. is then admitted and the radiator completely submerged in a tank of water in a similar manner to that shown in Fig. 162. The presence of air leaks caused by faulty joints or those too weak to withstand the pressure will at once be revealed by the air bubbles which issue. The places of leakage should be marked with small metal clips or, on removal from the tank, with a copying ink pencil. If a bicycle or motor pattern valve is installed the tank can be subjected to a prolonged air pressure test, using a pressure gauge connected by suitable tubing to one of the outlets.

After refitting a radiator to the chassis of a car, new water hose connexions should be employed. The cooling system should then be filled with soft water and all possible sources of water leakage examined. In particular, the hose clip joints and cylinder head gaskets should be checked for leakages.

The Water Pump. The water pump is generally of the curved blade impeller type which draws the water in at its centre and expels it by centrifugal action from its periphery. The pump impeller spindle may be driven from one of the auxiliary drives such as that operating the dynamo or ignition unit. Alternatively, it may be driven by the fan belt or may be integral with the belt-driven fan shaft.

The principal items of attention in the ordinary water pump are the *lubrication of the impeller spindle* and the *water gland unit*, which prevents leakage of water from inside the pump past the spindle.

In some of the more recent designs of pump, e.g. the Wolseley and A.E.C., a special carbon packing is employed which prevents water leakage and obviates lubrication.

Fig. 165 illustrates the various components of an Austin water circulating pump, the different items of which are indicated in the caption below the illustration.

The spindle is usually lubricated by means of a screw-down or grease-gun nipple form of greaser. The spindle should be lubricated at frequent intervals, namely, about every 500 miles of road use.

In regard to the pump gland (Fig. 166) this should be

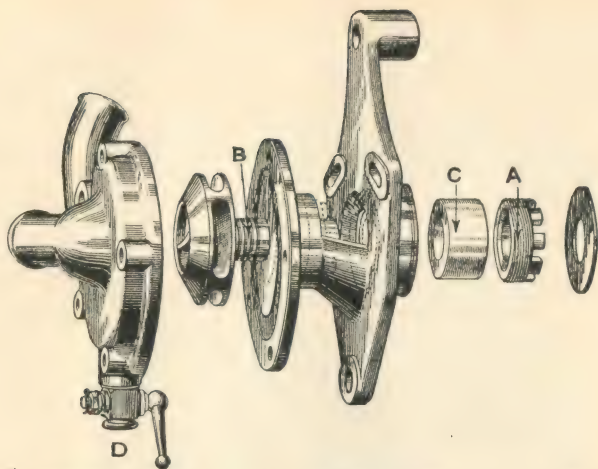


FIG. 165. COMPONENTS OF AUSTIN WATER CIRCULATING PUMP
A = Adjusting nut. *B* = Impeller and spindle. *C* = Special packing ring.
D = Pump casing drain cock.

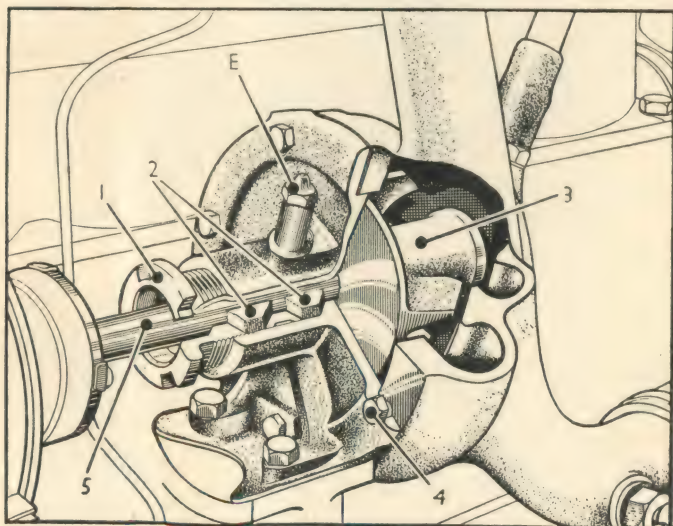


FIG. 166. AN AUSTIN WATER PUMP

- | | | |
|-------------|------------------|-------------------------|
| 1=Gland nut | 2=Gland packings | 3=Water pump valve |
| 4=Setscrews | 5=Spindle | <i>E</i> =Grease nipple |

adjusted whenever there are signs of leakage, such as beads of water emerging from the gland.

The gland should only be tightened sufficiently to stop the leakage. *Excessive tightening of the gland nut* should be avoided as this may cause seizure of the spindle.

When, as a result of lengthy service, the gland reaches

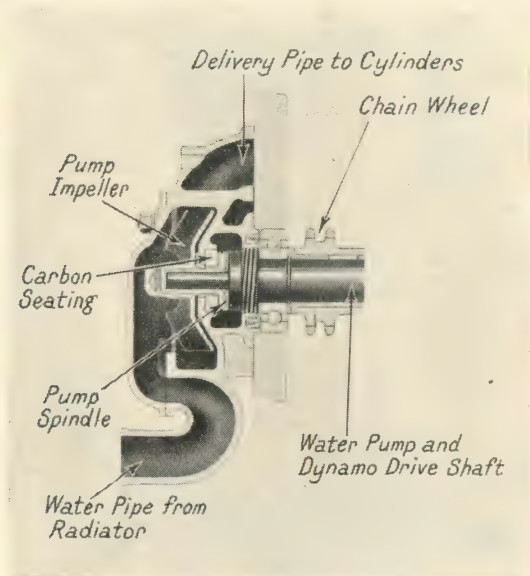


FIG. 167. THE A.E.C. WATER PUMP

the limit of its travel it will be necessary to fit new packing. The old remaining packing should be worked out with a piece of wire and the new packing, supplied by the makers of the car, fitted into position.

If this packing is not available, asbestos string smeared with graphite can be used.

It should here be mentioned that the use of the spindle lubricator often prevents leakage of water along the spindle.

Frozen Water Pump. Unless the water is drained from the water pump casing when the car is left standing under

freezing temperature conditions, the water in the casing will freeze and thus lock the impeller. When the engine is subsequently started up, the impeller spindle will probably shear off; in addition the pump casing will no doubt crack as a result of the water within it freezing. The importance

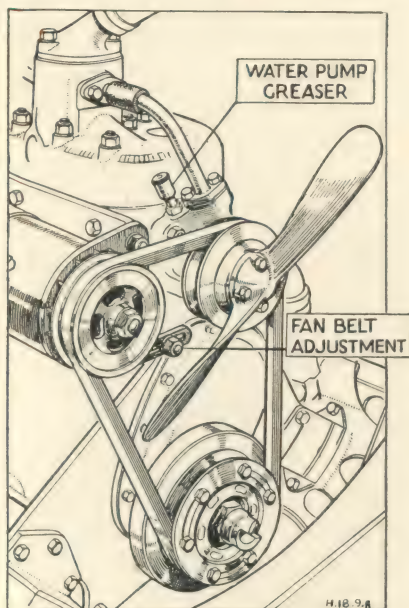


FIG. 168. FAN BELT ADJUSTMENT (AUSTIN)

of draining the water pump casing will therefore be appreciated.

Carbon Seating Pumps. The carbon-block packing used instead of water gland packing in some pumps will give a long period of service, but when it becomes worn too thin it must be replaced. The carbon packing in some cases, e.g. the A.E.C. pump, is carried in a steel sleeve which can be removed from the pump casing and spindle. As the carbon is a tight fit in this sleeve, it is necessary to heat it in oil until the expansion frees the carbon.

Similarly, before renewing a carbon block, the sleeve should be heated over a gas jet until it just commences to show an oxide colour, when the new carbon block can be dropped into position; when the spindle cools down it will be found that the carbon is gripped securely. The seating is made slightly convex so that it quickly gives a bearing all round; one of $\frac{1}{8}$ in. width is satisfactory for leakage prevention. It should be noted, when replacing the carbon element in the pump, that there is a compression spring inside the hollow stainless steel spindle.

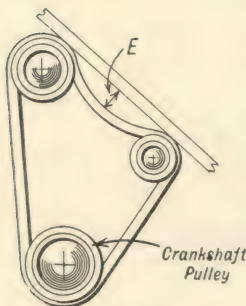


FIG. 169. FAN BELT TENSION

The Fan Belt. The fan belt must be kept sufficiently tight to prevent any slip; it should not be too tight, however, or the fan bearings will heat up or wear prematurely. Usually the belt should be adjusted so that the centre part between any two pulleys has a lateral play at *E*, in Fig. 169, of about 1 in. for normal car engine arrangements.

Anti-freezing Mixtures. There is a number of possible anti-freeze compounds for use in very cold weather of which the better known ones are alcohol, glycerine, and ethylene glycol—marketed under different trade names. Solutions containing calcium salts should be avoided as these usually cause electrolytic action (or corrosion). Other anti-freeze products to avoid are those containing glucose or honey.

When alcohol is used, the system should be kept airtight since the alcohol content is liable, otherwise, to evaporate. A mixture of 20 per cent glycerine and 80 per cent water has a freezing temperature of 21° F. (i.e. 11° below zero F.); one of 30 per cent glycerine and 70 per cent water freezes at 12° F.; and one of 40 per cent glycerine and 60 per cent water, 0° F. (i.e. 32° of frost).

Among the proprietary anti-freeze solutions that can be recommended are Smith's "Bluecol," Vacuum "Voco Anti-Freeze," and Price's "Zero."

It is important before using anti-freeze solutions to

tighten the cylinder head bolts, or test for tightness, since these liquids have a contaminating effect upon cylinder oils. Further, all of the water in the cooling system should first be drained away, including that in the water pump casing; otherwise pockets of water may remain to cause freezing cracks.

The radiator hose connections should be checked for leakages after filling with anti-freeze solution.

Anti-freeze solution should be added to the radiator when the engine is cold.

Overheating. Overheating, as shown by the water boiling in radiator system, may be caused by (1) a slack fan belt; (2) faulty water circulating pump; (3) ignition too far retarded; (4) excessive carbon deposit; (5) partial or complete failure of the engine lubrication system; (6) insufficient water in cooling system due to leakage or other cause; (7) clogged radiator or water system; the use of so-called *radiator leak prevention compounds* will often cause clogging of the fine radiator water passages; (8) constant operation on over-rich mixtures—due, often, to the carburettor choke used for starting not having been returned to the normal running position; (9) over-weak mixtures; these also cause “popping-back” in the induction pipe and carburettor passages.

CHAPTER X

REASSEMBLING THE ENGINE

THE order of reassembly of the engine components should, generally, be the reverse of that of dismantling, but, in the course of reconditioning, the crankshaft and big-end bearings will probably be the first completed so that the suggested order of replacement will then be as

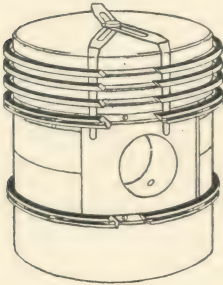


FIG. 170

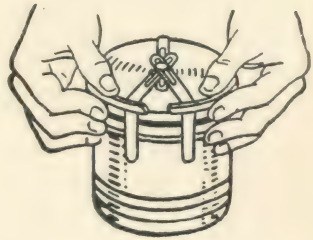


FIG. 171

follows: crankshaft, main bearings, connecting-rod, pistons, valves, timing gear, and, finally, the cylinder head and crankcase sump. The other parts, such as the inlet and exhaust manifolds, exhaust pipe, carburettor and ignition unit, etc., can be left until the last.

Replacing the Pistons. Before the pistons are replaced it is, of course, necessary to fit the rings in their grooves. Unless special care is exercised in this operation there is a risk of fracturing the cast-iron rings, so that it is advisable to use some form of piston ring replacement device, such as the Brico pattern shown in Fig. 170. It consists of three slotted angular strips which are clamped at the centre as shown and spaced at 120 degrees apart. The strips are narrow in width and of small thickness, so that the piston rings can be sprung over them and will clear the piston slots. The method of replacing the rings is illustrated

in Fig. 171; after the rings are in position, the device in question is moved upwards so as to allow the rings to fall into their respective slots.

When the rings have been replaced it is necessary to compress them into their slots before the piston can be inserted into the cylinder. The rings must be so located that their

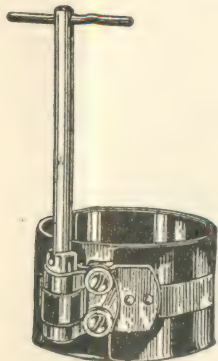


FIG. 172. PISTON RING
COMPRESSING TOOL

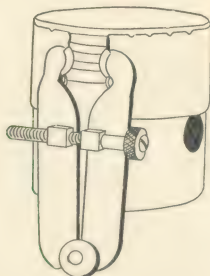


FIG. 173. ANOTHER PATTERN
PISTON RING COMPRESSOR

slots are not in line but staggered so as to provide the maximum length of path for any gas leakage that may occur.

A suitable tool for compressing the whole of the rings above the skirt of the piston is illustrated in Fig. 172. It consists of a contractable steel band operated by the handle shown. Another useful tool for the same purpose, but suitable for cases where pistons are replaced from the lower end of the cylinder, is shown in Fig. 173.

A method of employing a flexible metal band and external spiral spring, which enables the piston merely to be pushed straight down into the cylinder, is shown in Fig. 174. It has a conical mouth so that as the piston is pushed down the rings gradually contract to the cylinder barrel size at the bottom. The two devices given in Figs. 173 and 175 are only clamped lightly, so that the piston will slide readily through them and into the cylinder. It is advisable to oil or grease the insides of the flexible bands before placing them over the pistons.

The Engine Unit. When the engine has been assembled completely on the bench or stand and is replaced bodily in the chassis, care is necessary to ensure the correct location of the engine on its chassis bearers. If the advice on the marking of the engine bracket positions on the chassis bearers, given in Chapter II, has been carried out, there should be no difficulty in locating the engine correctly.

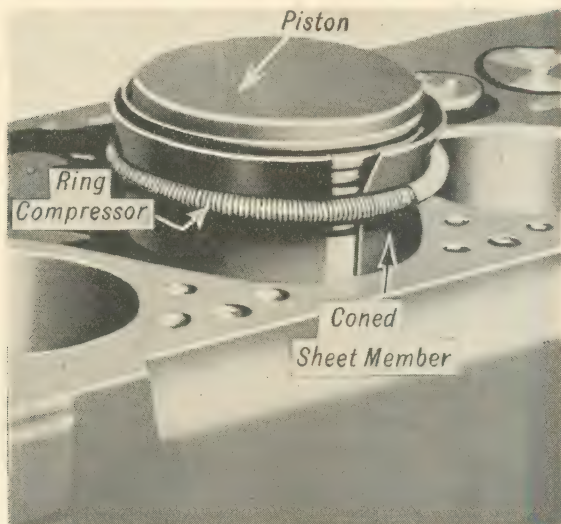


FIG. 174. REPLACING THE PISTON IN CYLINDER BARREL

The modern design of engine mounting having flexible rubber supports simplifies engine location after replacement, more particularly when the clutch and gearbox are built integrally with the engine—for then there is no question of having to re-align the engine and gearbox. If, however, the gearbox is separate from the engine and has not been removed from the chassis, the engine, after replacement in the chassis, should be checked for alinement by fastening a piece of metal strip or stout wire to the (disconnected) gearbox mainshaft flange or coupling and arranging the other end of the strip or wire so that upon rotating the gear

shaft it describes a circular path around the engine flywheel or clutch. The engine should then be located so that the circle described by the gear shaft indicator is concentric with the flywheel and the distance of the indicator point from the plane of the flywheel is the same all round (Fig. 176). The indicator in position *A* is used to check the concentricity of the engine and gear shaft, and in position *B* the alinement of the axes of the engine crankshaft and gear shaft.

Unless the alinement is correct, there may be increased wear in the bearings and in the coupling—if of the metal pattern.

Replacing the Cylinder Head. Assuming that the engine has been decarbonized and all traces of carbon and dirt

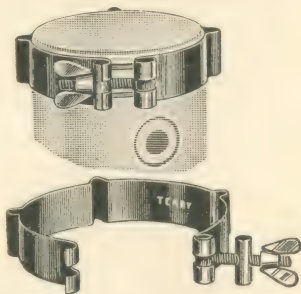


FIG. 175. THE TERRY PISTON RING COMPRESSOR

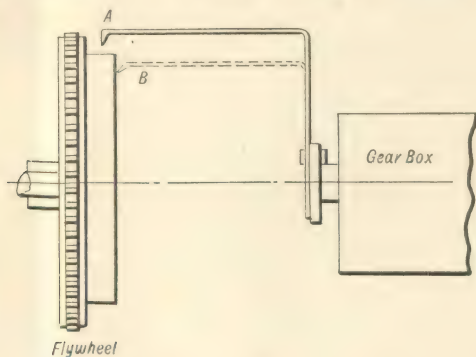


FIG. 176. CHECKING ENGINE ALINEMENT

removed from the top face and pistons and valve heads, the cylinder head should be treated similarly and the gasket examined for dents or other damage; if any are found, a new gasket should be used.

Before replacing the cylinder gasket examine the cylinder head studs at their junction with the machined face of the block for hard deposits such as *AA* (Fig. 177). Unless these are removed the gasket may not bed down properly on to the machined face.

Before replacing the cylinder head, see that the nuts screw down easily on their studs and that none of the latter

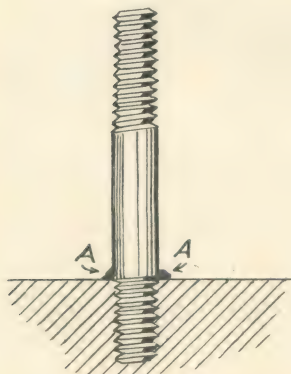


FIG. 177

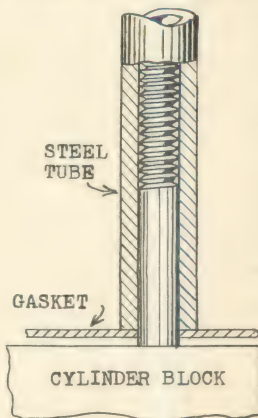


FIG. 178

are loose in the cylinder block. Also clean out deposits from the water holes in the head and block.

The cylinder barrels should be well smeared with perfectly clean engine oil and the crankshaft given a few turns by hand. It will then be found that the surplus oil from the cylinder walls has been scraped away on to the edges of the piston crown. This oil should be wiped off before replacing the cylinder head.

The cylinder gasket, before replacement over the cylinder studs, should be lightly smeared with a cylinder jointing preparation, such as "Osotite" or "Hermatite." Gold size, coach varnish, or even engine oil will give satisfactory results as a seal for the gasket since these materials become carbonized under the high cylinder temperature conditions and prevent leakage past the gasket.

When replacing the latter over the cylinder studs do not

use force, but proceed gradually all round, pressing gently to move it downwards over the studs; a piece of tube or a box spanner pushed over the studs will help to push the gasket into position. (Fig. 178).

The cylinder head of the ordinary car engine should first be lifted and placed so as to rest on the tops of the studs.

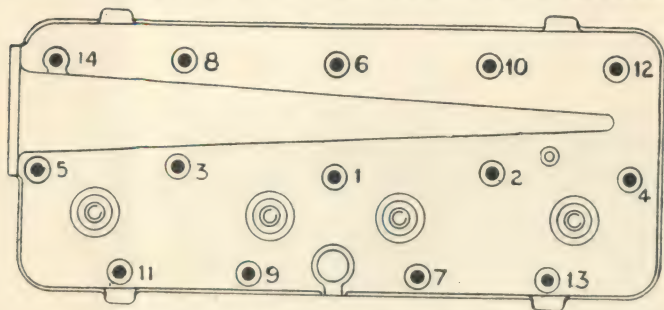


FIG. 179. ORDER OF TIGHTENING CYLINDER HEAD NUTS

Then, by standing astride the engine, the operator can lift and then lower the head on to the cylinder block.

The nuts (and washers, if provided) should then be replaced on all the studs, screwing the nuts up finger tight only. The nuts should then be partly tightened with a box spanner *in the definite order recommended by the manufacturers*. Usually, the order of tightening is that of commencing at the centre and tightening the nuts in an opening spiral order to ensure that the head is tightened from the centre outwards, in order to avoid distortion in the tightening process.

Figs. 179 and 180 illustrate the orders of loosening and tightening the cylinder head nuts on a four and six cylinder engine, respectively.

It is important to tighten each nut a little at a time so that it will be necessary to repeat the tightening procedure about four or five times before the head is properly tightened. A torque wrench is here an advantage.

Finally, replace the other cylinder head fittings, e.g. carburettor, inlet and exhaust manifold, ignition unit, water joints, etc., in cases where these parts are mounted on the

cylinder head. The carburettor throttle (or accelerator) and choke controls, petrol pipe union, cables, etc., should then be connected again and a careful examination made of all the external engine fittings to see that everything is in order. If all the engine components, nuts, bolts, and washers have been kept in boxes after the dismantling operation, the fact of any of these items remaining in their

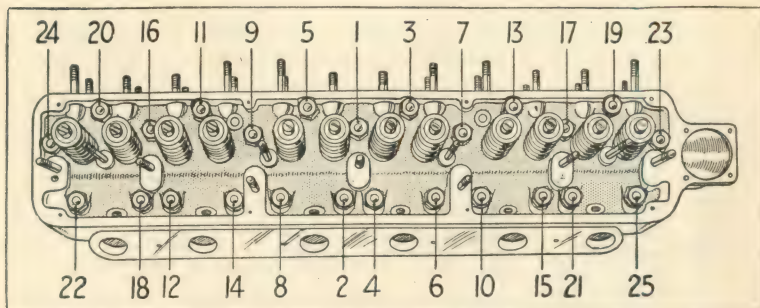


FIG. 180. TYPICAL SIX CYLINDER HEAD, SHOWING NUT TIGHTENING ORDER

boxes or otherwise, will be a check on their correct replacement.

Stud Removing Methods. When it is necessary to remove a cylinder stud which may have a damaged thread or become bent, if the stud is not to be used again it can be unscrewed with the aid of a crocodile jaw or pipe wrench; otherwise parallel flats can be filed on the sides so that it can be unscrewed with an adjustable spanner.

The usual workshop method for inserting or removing a stud is to employ a pair of nuts on the upper portion of the thread (Fig. 181). The nuts are locked together by placing a set spanner on each and pulling these together. To insert the stud the spanner is applied to the top nut; for removal, it is used on the lower nut. The nuts can readily be unlocked by using a pair of set spanners in the reverse direction to that for locking them. Special stud boxes are also used for stud insertion.

Removing Broken Studs. Studs which have broken off

above the machined surface of the cylinder block may be removed with a crocodile jaw spanner or pipe wrench or by filing parallel flats and using an adjustable spanner.

If *broken off flush with the surface*, one method of removal is to drill a hole of about two-thirds the stud diameter down into the centre of the stud for a depth of about $\frac{1}{2}$ in. and then tap the tang of a file into the hole, using the file to unscrew the stud.

Special stud removal tools on the reversed screw thread principle are sold for a similar purpose, the tool being inserted into the hole and then used with a tap wrench to unscrew the stud.

Another method is to resistance-weld a piece of steel rod to the broken end of the stud and then use the rod for unscrewing purposes.

In very stubborn cases it is generally necessary to drill a hole of diameter equal to the tapping or core diameter of the stud thread and then to use a set of taps to clean out the threaded hole.

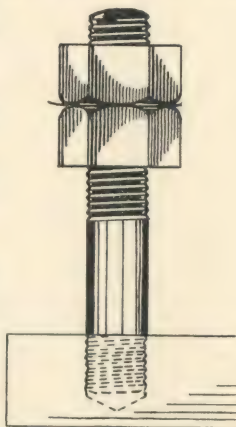


FIG. 181

Running a Reconditioned Engine. After replacing the cylinder head and its fittings, if the valve clearances have not already been set before the head was replaced—and this is possible on side-valve and overhead camshaft, but not push-rod operated overhead-valve engines—these should now be set. It is advisable with reground valves to allow from 1- to 2-thousandths inch greater stem clearances than the manufacturers' recommended values, to provide for subsequent bedding down after the engine has been working for a few hundred miles.

The engine sump should be refilled with new oil of the correct grade and the fan bearing lubricated.

Next, the radiator should be filled with soft water (filtered rain water will do if no other source is available). After filling, carefully inspect all the hose and other water joints, including the pump spindle gland and the thermostat

connexion, for leakages—as these frequently occur after reassembly of the radiator and engine.

It is as well to check the valve and ignition timing and the sparking plug point gaps—if this has not already been done or the former two items have not been disturbed.

The petrol supply is then turned on to the carburettor and, with the controls set for starting, but with the ignition switch “Off,” the engine should be cranked around for a few turns, using the starting handle. This will not only ensure that the engine is quite “free,” but will enable the pistons to draw sufficient mixture into their cylinders for starting.

If everything is in good order, switch on the ignition and start the engine, keeping it throttled down to its usual idling speed. Allow the engine to run for about fifteen minutes or so, noting its behaviour and watching for leaky joints, e.g. water, exhaust, or cylinder gasket. Then increase the speed of the engine and allow it to warm up to its normal temperature, but first check from the oil pressure gauge readings whether the lubrication system is working satisfactorily.

Do not allow the engine to run long enough to “boil” the water in the cooling system, but switch off the engine before the water becomes too hot.

Finally, go over each of the cylinder head nuts again, with a spanner, checking these in the proper order in which they were tightened down, previously; it will generally be found that each can be given about half a turn more.

It is a good plan, also, to check over the exhaust and inlet manifold joints, exhaust pipe joint, and carburettor union nuts at the same time; also the valve stem clearances.

When this has been done, the carburettor slow-running device should be reset for slow-running or “idling.”

Use of Graphited Oil for Running-in. When cylinders have been rebored and new pistons fitted, the big-end or main bearings have been taken up, or when new rings have been fitted to the pistons, it is a good plan to employ a graphited lubricating oil in the crankcase for the first thousand miles or so. For this purpose about one pint of Acheson’s colloidal graphite solution per gallon of lubricating oil should be used. The graphite particles, which are of

microscopical size, tend to fill the hollows in the bearing surfaces and thus provide efficient lubrication even in the event of the oil film becoming broken; tool-marked cylinder walls or slightly pitted surfaces are effectively treated in this manner. Tests have shown that a graphited oil reduces the friction by about 15 per cent between engine bearing surfaces.

Upper cylinder lubricant is another recommended product. In this case about half an ounce of lubricant per two gallons of petrol is employed. This ensures the lubrication of the cylinder walls and valve guides, especially when an engine is started from cold, after the previous heated oil has drained away to a large extent. Suitable upper cylinder lubricants include Wakefield's "Castrollo," Gargoyle Upper Cylinder Lubricant, and Shell Upper Cylinder Lubricant; these oils should be used in the proportions previously mentioned.

Running-in Rebored Engines. In the case of rebored engines, it is a common practice to fit the pistons slightly on the tight side and to run the engine in afterwards.

In the larger motor repair works the engine is coupled to an electric dynamometer and is *motored around with this machine for two or three hours at least*, with the petrol and ignition shut or switched off. Afterwards the engine is started up and run under its own power at a low speed and under a light load for several hours. It is then stopped and if, on examination, everything is in perfect order, the speed is gradually increased for the next few hours. Finally, it is given a full load test, the horse-power output being measured by the dynamometer and compared with the maker's original test figure.

During these tests the cooling water is maintained at its normal working value. A complete running-in and power test should occupy not less than ten hours.

In the smaller motor garages *engines may be run-in, after reboring, in their own chassis*. In order to keep the cooling water at its proper temperature the drain cock should be opened and a supply of cold (mains) water led to the opened radiator filler orifice. A thermometer should be inserted somewhere between the cylinder head and upper water tank for checking the water temperature.

The engine should be run at a moderate speed, say between 500 and 750 r.p.m., for a period of twelve to twenty-four hours under these conditions.

After an engine has been run-in on the brake or in the chassis in the manners prescribed, it should be treated by the driver, for the first few hundred miles, in the same way as a new engine.

At the end of this period the crankcase sump should be drained and refilled with new oil. The valve stem clearances should also be checked at the same time and the cylinder head nuts tested for tightness.

At this stage the carburettor may be conveniently tuned up to give the best road performance with reasonable petrol economy.

Similarly, it may be advisable to check the ignition timing, giving the maximum advance that the engine will take without knocking or losing power; this will ensure maximum performance combined with fuel economy.

Testing the Compressions of the Cylinders. The compression pressures of the cylinders afford a reliable indication of the condition of the cylinders, pistons, rings, and valves. If the compression pressure is satisfactory and is maintained without rapid loss, then the engine may be assumed to be in good condition. On the other hand, the inability of a cylinder to show a good compression or to hold its compression, indicates leakage of the charge past the piston or valve seatings.

In order to obtain the most reliable results the engine's compression should be tested in the "hot" state, i.e. at the normal working temperature of the engine. If tested with the engine cold, the lubricating oil on the cylinder walls may be much thicker, owing to gumming effects, and will give a misleading compression test result.

It is also important to note when testing compressions that *these should be equal for all the cylinders*; if one cylinder shows an appreciably lower value than the rest, this indicates some defect in the piston, rings, cylinder wall, or valves and seatings of the particular cylinder.

Compression Testing Devices. For ordinary test purposes the compression pressure may be taken with the engine stationary, using some form of pressure gauge reading up

to about 150 lb. per sq. in. A suitable gauge unit for this purpose is the Stromberg one shown in Fig. 182. To use this gauge the engine is first warmed up and then its sparking plugs are removed and the hard rubber conical end of the gauge unit is held firmly in each of the sparking plug holes in turn, while the crankshaft is given several turns by hand; the highest reading of the gauge should be taken in each case. For this test it is essential for the carburettor throttle to be in the full open position.

There is another kind of compression tester that can also be used to measure the maximum explosion pressure while the engine is working. It is known as the Okill Pressure Indicator and is screwed into the sparking plug hole for compression tests. For explosion pressure tests, however, it is necessary to screw it into another hole in the cylinder head or to use an adapter to take both the sparking plug and itself, for use in the sparking plug hole.

This device (Fig. 183) consists of a small piston and cylinder, the former being a good working fit in the latter. The piston moves upwards in the cylinder against the pressure of a helical spring which is specially calibrated. To use the indicator, the milled head on the cap is screwed up or down until the spring pressure on the piston just balances the compression pressure as the engine is cranked or motored around at a slow speed with the ignition switch "Off." A small indicator needle or pointer, which can vibrate to and fro, shows when the two pressures are in balance. The pressure in lb. per sq. in. can then be read off the drum of the indicator or, in another pattern, from a kind of cyclometer dial on the side of the instrument.

To use the indicator for explosion pressures the milled cap is screwed until the indicator lever on the left side just ceases to vibrate; this indicates that the explosion and spring pressures are then in proper balance on the small piston. The pressure reading can then be read off the scale as before.

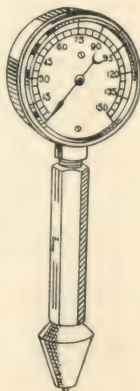


FIG. 182

For prolonged explosion pressure tests it is necessary to have a water-cooled adapter; otherwise the temperature effect on the spring may give misleading results.

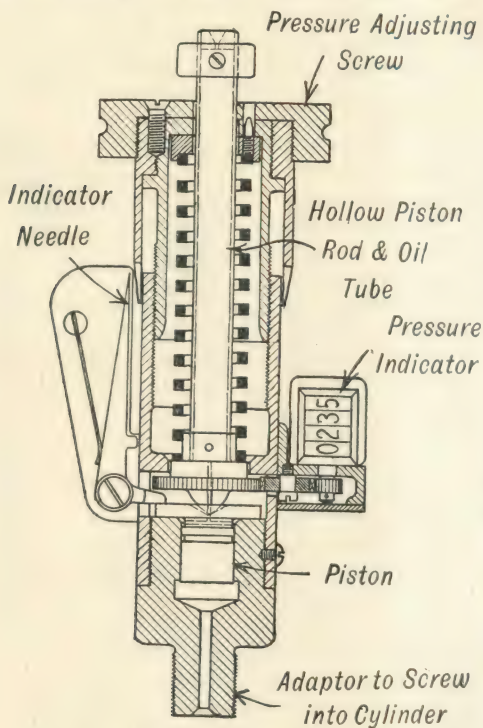


FIG. 183. OKILL PRESSURE INDICATOR

Testing Reconditioned Engines. Apart from actual road tests, reconditioned engines may conveniently be tested in the works by means of a power brake or dynamometer; these are devices for absorbing or transmitting the power of the engine and, at the same time, measuring the power. As it is possible in most power brakes to alter the load and speed, a series of readings of brake horse-power and engine speeds may be obtained over the whole speed range. These

values may then be compared with the engine manufacturers' figures or, from a knowledge of the engine dimensions, compression ratio, etc., compared with computed values of horse-power that would be expected from such an engine.

The simplest type of power absorption brake is the fan brake, of which the Walker type is a typical one. It consists of a pair of arms attached to the engine shaft. At the ends of the arms are sheet plates which act as paddles

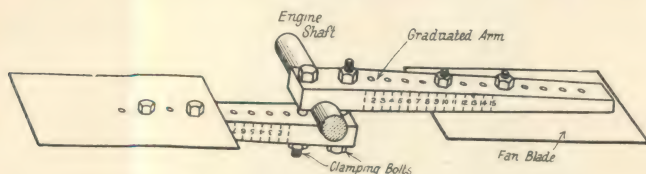


FIG. 184. THE WALKER FAN BRAKE

to absorb the engine power; the load on the engine is varied by altering the size of plate and its radius of action. The horse-power absorbed varies as the cube of the engine revolutions; the fan brake manufacturers supply curves of speed and horse-power values for different sizes of brake.

The hydraulic brake used in many of the larger works operates upon the principle of a paddle rotating within a chamber filled with water. The casing of this brake is mounted on bearings and its torque or turning tendency is measured by means of weights or a spring balance. Knowing the excess weight on the balance arm and the engine speed, the horse-power can be estimated. The Froude hydraulic brake operates on this principle.

The electric brake or dynamometer employs an electric generator to absorb the engine's power output, instead of the hydraulic brake, but it employs the same method, viz. torque reaction, of measuring the power.

Fuller particulars on the subject of testing motor vehicle engines will be found in *Testing of High Speed Internal Combustion Engines*, A. W. Judge (Chapman & Hall, Ltd., London).

Running-in New Engines on the Road. In the case of new or rebored engines which can only be run in when the car is on the road, it is important—if the best performance and longest life are to be obtained—that the engine speeds should be kept down for the first 500 to 1000 miles.

A good plan for mass-production car engines is to keep the top gear speed down to 30 to 35 m.p.h. for the first 500 miles, with correspondingly lower speeds for other gears. Thus in the case of a typical engine, namely the Austin Ten, the recommended maximum road speeds are—

Top gear	.	.	30–35 m.p.h.
Third gear	.	.	19–20 m.p.h.
Second gear	.	.	12–13 m.p.h.
First gear	.	.	7–8 m.p.h.
Reverse	.	.	4–5 m.p.h.

For the Morris cars, the third, second and bottom gear speeds should not exceed 26, 15 and 10 m.p.h., respectively. In some of the new model car engines higher running in road speeds are allowed. Thus, in the case of the Standard Twelve car, the maximum top gear speeds, for the first 250, next 150, and following 100 miles should not exceed 40, 45, and 55 m.p.h., respectively. The maximum speeds on the other gears, viz. 3rd, 2nd, and 1st, should not exceed, 35, 20, and 10 m.p.h. for the first 500 miles.

Between the first 500 and 1000 miles of running these speeds may be increased gradually to the normal cruising speeds. Over 1000 m.p.h. it can be assumed that the engine piston, cylinder surfaces, and main and big-end bearings have then become properly bedded down.

As mentioned earlier, the oil sump should be drained at 500 miles. The use of an upper cylinder lubricant with colloidal graphite content is advised for the first 1000 miles.

CHAPTER XI

THE LUBRICATING SYSTEM

It is essential for the motor mechanic to understand thoroughly the principle and operation of the engine oiling system and, further, to know how to diagnose and rectify any troubles that may occur. Although there is a certain

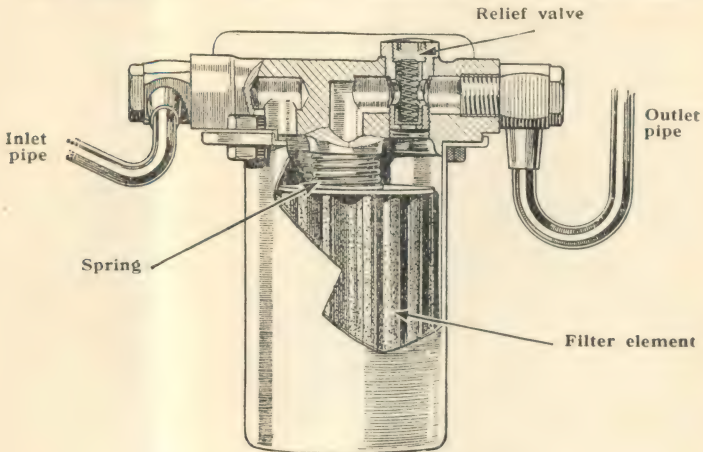


FIG. 185. FELT ELEMENT OIL FILTER

amount of scattered information on this subject in the present volume, it is proposed to give in this chapter a brief outline of the principles and possible faults that may arise.

The most widely used lubrication system, in modern cars, is the full pressure one, wherein oil is drawn by a pump from the engine sump and is pumped under pressure to the main and big-end bearings, via the drilled crankshaft. A separate supply is taken to the overhead valve mechanism in engines of this type and provision is made for lubricating, automatically, the timing gears and camshaft bearings.

Typical Engine Lubrication Systems. The layout of the lubrication of a four-cylinder side valve engine is well illustrated in the case of the Austin 10 h.p. engine shown, schematically, in Fig. 186. In this system the vertical shaft *V* is driven by means of skew gearing off the camshaft and at its lower end it drives a submerged gear

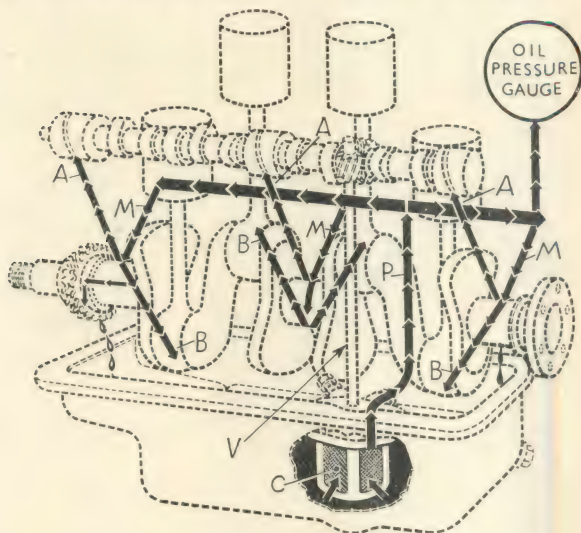


FIG. 186. AUSTIN TEN LUBRICATING SYSTEM

wheel type oil pressure pump housed in the filter chamber *U*, so that all oil taken at the suction side of the pump is properly filtered. From the delivery (pressure) side of the pump the oil is delivered along the pipe *P* to the oil gallery above whence it flows through the oil pipes *M* to the three main bearings of the crankshaft. The latter is drilled in such a manner that the oil from the main bearings flows internally through the crankshaft and is there directed through suitable outlet holes to the big-end bearings *B*. A supply of oil is also taken to the camshaft bearings *A* and there is a connexion on the right-hand side of the oil gallery to the oil pressure gauge. When cold the oil pressure

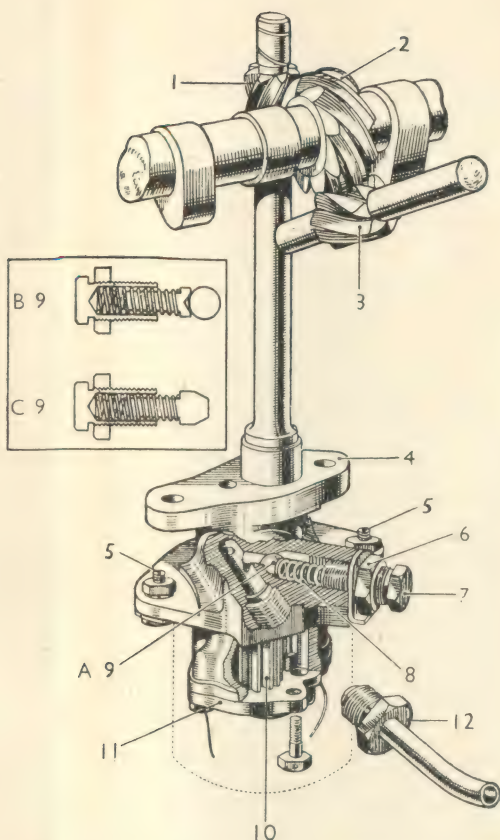


FIG. 187 VAUXHALL (BEDFORD) OIL PUMP AND DRIVE

1. Pump spindle drive. 2. Camshaft gear. 3. Ignition distributor gear. 4. Oil pump body. 5. Gauze strainer retaining screws. 6. Relief valve locknut and washer. 7. Relief valve retaining bolt. 8. Relief valve spring. 9A. Relief valve ball. 9B. Later model relief valve. 9C. Current type relief valve. 10. Pump gears. 11. Bottom cover. 12. Gland nut and delivery pipe.

reading is about 40 lb. per sq. in., but as the engine and oil warm up this drops to 30–35 lb. per sq. in.

The Oil Pressure Relief Valve. An oil pressure relief valve (shown in Fig. 187) is fitted to the lubrication systems of automobile engines in order to regulate and also to limit the maximum pressure. It is of the spring-loaded ball valve pattern (Fig. 188) and has an adjustment screw

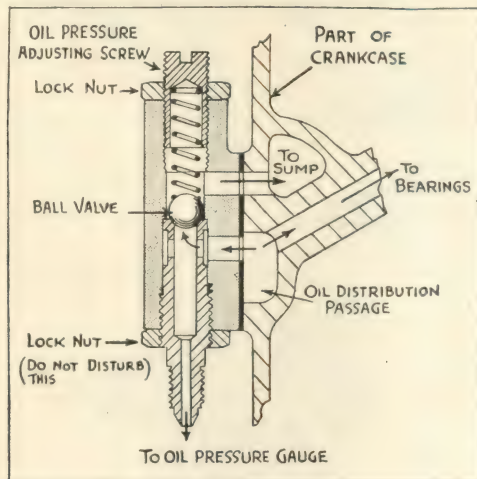


FIG. 188. OIL PRESSURE REGULATOR

to alter the closing tension of the spring on the ball valve, and thus to alter the opening oil pressure. If, for any reason the pressure should tend to rise above the correctly adjusted value the ball valve opens and relieves the pressure; after adjustment the screw is locked by means of a nut.

Overhead Valve Lubrication System. The layout of a modern overhead valve Bedford* engine is illustrated in Fig. 189. The arrows indicate the direction of flow of the oil. The oil is drawn by the submerged gear-wheel type of pump, on the lower left-hand side, in Fig. 189, and is delivered to an oil distribution gallery, whence it is directed to the main bearings and to the camshaft bearings, as

* Vauxhall Motor Co. Ltd., Luton.

depicted by the arrows. From the big-end bearings oil is allowed to escape through holes in the upper bearings and

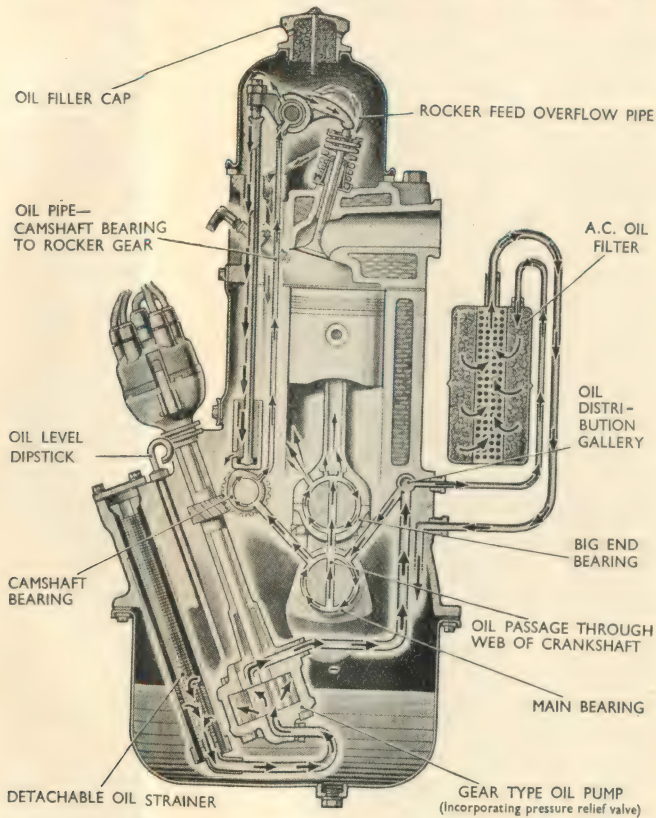


FIG. 189. BEDFORD OVERHEAD VALVE ENGINE LUBRICATION SYSTEM

connecting rod ends, so as to spray the cylinder walls once every revolution, at the top strokes of the pistons. From the camshaft bearing a small supply of oil is taken, by the vertical pipe shown, to the valve rocker bearings above. The surplus oil, after lubricating the valve gear,

flows down the side of the push rods, through the hollow tappets and out *via* small holes to return to the oil sump in the base of the crank chamber. A felt seal is fitted at the top of each inlet valve guide to prevent oil passing in excess to the valve guides.

The timing gears are lubricated by a jet of oil from the camshaft front bearing.

A portion of the oil entering the main distribution gallery is circulated through an *AC* felt filter, where it is cleaned and then returned to the oil sump by the right-hand pipe, shown in Fig. 189.

This filters the whole of the oil in the sump about 12 times an hour and it has a useful filter element life of 6000 miles, after which it must be renewed. This lubricating system includes an *oil pressure warning light* on the instrument panel which indicates lubrication system trouble either by flickering all the time the engine is running at its normal speeds or by lighting up continuously, whereas *it should go out* when the engine is running and the oil pressure is correct. The switch for the warning light is operated by oil pressure in such a way that when the engine is started and oil pressure is built up, the diaphragm-operated switch breaks the warning light circuit. The normal oil pressure for the system described is 25 to 35 lb. per sq. in.

The Oil Pump. The gear wheel type of pump shown in Fig. 191 is now widely used, although plunger-type pumps are occasionally employed. When an engine is dismantled the gear pump should also be taken down and examined for wear. All carbon and sludge must be removed from the relief valve bore and the relief valve parts dismantled, cleaned, and inspected. The valve should not be marked in any way and its seating should be quite clean and polished. Any burrs on the seating or valve (if of the cone type) must be removed before the unit is assembled. The oil relief valve spring may with advantage be replaced by a new one, as it tends to lose some of its strength in time. If the gear wheels show signs of wear they should be renewed, although it is important, in this case, to make sure that the barrels are not worn also; in the latter eventuality a complete new pump unit is indicated. Any burrs on the edges of the gears should be taken off before

re-assembly. The correct clearance between the gear wheels and casing is about 0.002 to 0.004 in. and the end clearance, or float, 0.0035 to 0.005 in.

After re-assembling the oil pump system it may be

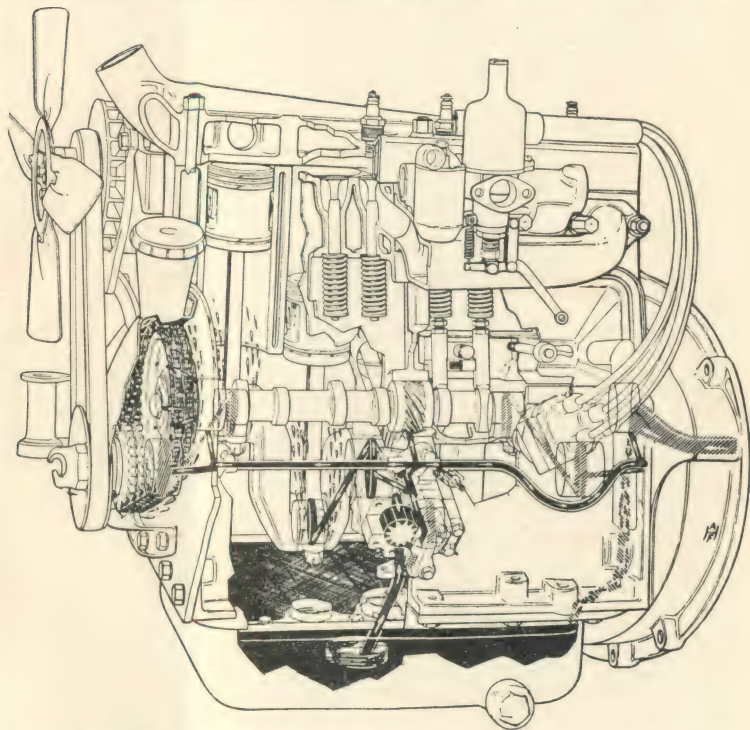


FIG. 190. MORRIS SIDE-VALVE ENGINE LUBRICATING SYSTEM

necessary to prime the pump by introducing oil down the delivery pipe before connecting it up.

When completely assembled the pump should be tested for delivery by rotating the engine crankshaft with one of the oil delivery unions, e.g. that of the oil gauge disconnected. Oil should flow from the disconnected item after a time.

It is important to ensure that all unions and gaskets in the oil system make proper oil-tight joints.

The Oil Filter. In the case of most car engines there is an oil filter in the oil replenishing orifice and this, being readily removable, should be kept clean. After every few thousand miles it should be removed and washed clean in a paraffin bath.

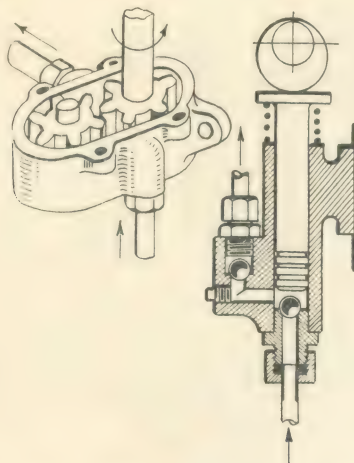


FIG. 191. SHOWING TYPICAL GEAR AND PLUNGER OIL PUMPS

Many modern automobile engines have a separate oil cleaner on the pressure side of the oil delivery side which cleans the oil continuously as in the example shown in Fig. 189. There is usually an oil filter on the suction side of the oil pump, also.

The oil cleaner is generally of the cylindrical or star-shaped felt filter element pattern. Every 2000 to 3000 miles the element should be removed and at the same time the sediment drain plug or cock opened to drain off the filtered deposits. The element can be cleaned by agitation in a petrol bath, but it is advisable after 6000 to 8000 miles of service to replace this element with a new one, obtainable at most garages or from accessory firms at small cost.

When the metal disc type filter, e.g. the Auto-Klean type, is fitted there is no renewable element; all that is necessary is to give the handle at the top of the filter an occasional turn, when the filtered matter is removed and falls to the sump below, whence it can be drained off after relatively long intervals by removing the drain plug.

Maintenance of Lubrication System. Commencing from the period when the engine is new, the oil should be drained out of the sump, whilst the engine is still "hot" at the end of the first 500 miles, to ensure that any solid particles such as metal burrs from inside the engine are removed. A re-bored engine should also be drained at 500 miles. Thereafter, the sump should be drained out at about 2000 to 3000 mile intervals; some manufacturers advise emptying the sump after the first 500 miles, then after the next 1000 miles and subsequently at 2000 to 3000 mile intervals.

The hot oil will drain out satisfactorily so that paraffin should not be used to wash out the sump (except when the latter has been removed from the engine, as during an overhaul). Flushing oil may, however, be used to clean the sump. At all times the oil should be maintained within the two limit marks on the dipstick or oil level gauge.

The oil pressure gauge or red warning light must be inspected during the running of the engine as this is the only external indication of the efficient working of the lubrication system.

The gauze filter in the oil sump filler should be removed and cleaned as previously stated and the oil cleaner (when fitted) attended to at the recommended intervals.

Testing the Lubrication System. After an overhaul, necessitating dismantling of the engine, the oiling system should always be checked for correct operation. If the oil pump is an external fitting or has an external delivery pipe, it is a simple matter, as stated previously, to test the pump for oil delivery by disconnecting the delivery side union and running the engine for a very short period. If oil oozes out of this broken joint, this indicates that the pump is working.

The oil pressure gauge reading is another indication that there is oil delivery by the pump, but the actual reading will show whether the delivery is too low or too high, according to the manufacturer's recommended value.

When an engine is cold, there is usually considerable obstruction to the initial oil flow due to the viscosity and inertia of the oil in the pipes and passages, so that a much higher oil pressure reading is usually given on starting from cold. Thus, if the normal working pressure is 25 to 30 lb. per sq. in. at a normal car speed of 30 to 35 m.p.h., the initial cold starting pressure will usually rise to 50 to 60 lb. per sq. in.

LUBRICATION SYSTEM TROUBLES

The following is a summary of the lubrication troubles likely to occur in modern engines, and their causes—

(A) *Low Oil Pressure Reading—*

- (1) Oil pressure release valve or seating dirty.
- (2) Oil pressure release valve spring tension too weak.
- (3) Oil leakage on pressure side, e.g. worn main bearings or leakage at union of an oil delivery pipe.
- (4) Oil pump gears worn.
- (5) Suction side filter clogged or too small mesh.

(B) *Excessive Oil Pressure—*

- (1) Engine oil too viscous, owing to too heavy grade or cold starting conditions.
- (2) Oil delivery pipe or passage clogged. Blocked oil cleaner, without by-pass valve.
- (3) Oil pressure release valve spring tension too great.
- (4) Oil pressure gauge reading incorrectly.

(C) *Failure to Indicate Oil Pressure—*

- (1) No oil in crankcase sump.
- (2) Oil pressure gauge pipe broken or restricted.
Leaky oil gauge union.
- (3) Faulty oil pressure gauge.
- (4) Oil pressure release valve stuck open due to defect or to broken spring.
- (5) Oil pump not working.
- (6) Oil suction pipe broken, disconnected, or clogged.

In some cases oil pumps will not commence to operate unless they are first primed with oil; this applies to cases where oil pumps have been dismantled for examination or overhaul and then replaced.

CHAPTER XII

MISCELLANEOUS MAINTENANCE AND TUNING ITEMS OF ATTENTION

The Ignition System.* The principal items of attention in the case of *the magneto* are: (1) the contact-breaker, (2) the distributor, (3) the carbon brushes, (4) lubrication.

The contact-breaker should be inspected and if necessary the contacts cleaned or trimmed and reset to the correct opening distance every 4000 to 5000 miles. The recommended gap for ordinary magnetos used on early model car engines is 0.012 to 0.014 in.

The contacts must be kept perfectly clean, i.e. free from oil, grease, or dust. The pivot bearing of the movable contact arm should also be kept clean and the arm should move freely on its pivot. If it should stick in the open position, this indicates a tight bearing and the latter should be eased; early pattern contact-breaker bushes were of fibre, and in damp weather were liable to swell and thus hold the contact points open.

The distributor rotor arm should be kept clean and all dirt, dust, or moisture removed from the inside of the distributor casing. If the jump-spark type distributor is fitted, see that the brass segment at the end of the rotor arm is not burnt down appreciably. The connexions of the high-tension cables should be tested for tightness by gently pulling the cables.

Where *carbon brushes* are used to pick up the h.t. current these should be kept clean and free in their guides; the brass contact members should be cleaned, periodically, with a petrol moistened rag. Do not increase the tension of the brush springs, or excessive wear of the brushes will occur. Replace worn brushes with new ones.

Lubrication of the magneto is effected by giving two or three drops—but no more—to the two armature shaft ball

* A full account of Ignition System Maintenance is given in another volume of this series, entitled *Automobile Electrical Maintenance*.

bearings, and to the distributor arm bearing, about once every 3000 miles.

Vertical type magnetos, such as the Lucas, B.T.-H., or Scintilla can be dealt with in a somewhat similar manner to the horizontal types, but as there are no carbon brushes (since the jump-spark type of distributor is used) and no half-speed distributor shaft, their maintenance is simplified. The bearings of the vertical shaft will require lubricating periodically, and, if the automatic ignition advance mechanism is fitted, the bearings of this should be given a spot of oil at long intervals. The cam of the contact-breaker should be given a light smear with grease every 3000 miles.

In the case of *coil ignition systems*, the principal items of maintenance attention are as follows, namely: (1) the contact-breaker unit, (2) the distributor unit, (3) lubrication. Fig. 192 illustrates the chief items of attention for a Lucas coil ignition unit.

The contact-breaker points should be kept clean and if necessary trimmed square. The contact-breaker gap should be maintained at about 0.010 to 0.012 in. maximum opening for Lucas equipment; most American units have gaps of 0.015 to 0.020 in., however.

The rotating cam operating the contact-breaker should be given a light smear of car grease or vaseline every 3000 miles. Do not give this an excess, however, or the surplus grease may get on to the contacts and there cause trouble.

The interior of the distributor casing should be kept quite clean and free from oil or grease. Further, the high-tension cable ends should be tested for tightness in the distributor head and the cable insulation examined for signs of cracks or perishing; if found, new cable must be fitted.

The only lubrication item of attention is that of the distributor shaft bearing; a lubricator of the oil or grease cup pattern is provided below the contact-breaker casing for this purpose. This item requires lubrication attention about every 500 miles. In some cases a single drop of oil on the contact-breaker moving arm bearing is advocated.

The high-tension coil seldom requires any attention, but after long intervals the cable end connexions to this coil should be removed for examination and cleaning, for

corrosion often occurs at the brass contacts on the ends of the cables.

The Sparking Plugs. The correct pattern sparking plug should be selected to suit the engine; in this connexion the "reach" of the plug points should be correct. The best

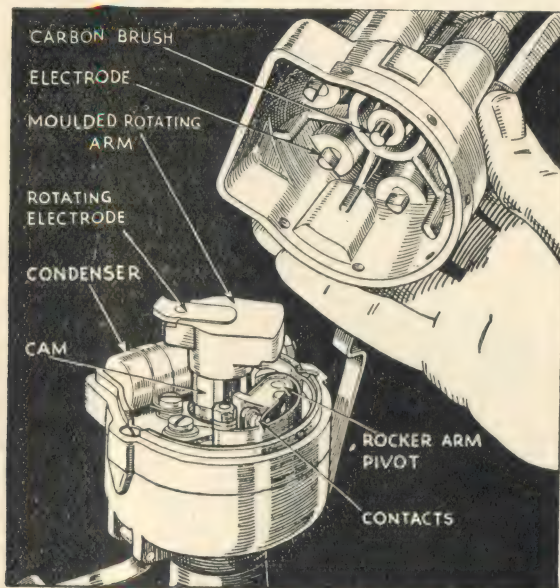


FIG. 192. CONTACT-BREAKER AND DISTRIBUTOR UNIT
(LUCAS)

position in regard to the sparking plug points is level or slightly below the surface of the combustion chamber wall; they should never project beyond.

Sparking plugs should be cleaned every time the engine is decarbonized, by means of a petrol bath or by the sand-blast method in order to get rid of any oil or carbon deposits on the insulation and electrodes.

A wire brush having fine wires fastened endwise or axially can be used for dislodging carbon deposits. If the plug can be dismantled (Fig. 193) it can readily be cleaned.

The gap of the sparking plug for horizontal type magnetos should be about 0.015 in. Low-compression engines can be given slightly greater, while high-compression ones should have rather less gap measurements than the value given. The correct gap for ordinary coil ignition systems is 0.018 to 0.020 in., but, in the case of recent American coil systems, gaps up to 0.030 in. are frequently employed.

Testing the Ignition System. When the engine refuses to start it is first necessary to ascertain whether this is caused by ignition or carburation trouble.

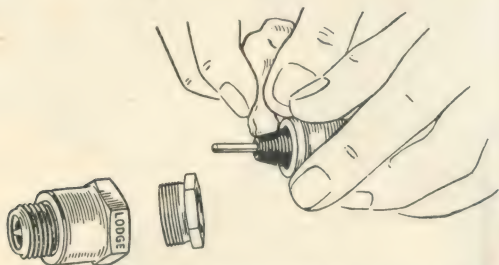


FIG. 193. CLEANING DISMANTLED SPARKING PLUG

The carburettor may be tested to see whether petrol is flowing into the jet by shutting the air choke valve and cranking the engine for several complete turns, when petrol should drip from the air inlet or below the main choke; if a carburettor tickling device is fitted, this should be used.

The carburettor jets should be free and the petrol filter clean. Further, there should be no dirt or water in the base of the float chamber.

To test whether the cause of non-starting is due to carburettor trouble remove each sparking plug and introduce about half a teaspoonful of petrol into each cylinder through the plug hole. Replace the sparking plugs and, after switching on the ignition, motor or crank the engine with the throttle partly open. If the engine fires a few times and then stops, this clearly indicates carburettor trouble, since the ignition system will thus have been proved correct.

If the engine fails to fire, the cause is no doubt that of

ignition trouble, and this may in turn be due to one of the following items—

- (1) Contact-breaker moving arm stuck open.
- (2) Ignition switch may be "Off" or faulty in operation.
- (3) One of the leads to the high-tension coil or distributor unit may be disconnected. The main battery and distributor arm leads should be examined for electrical continuity.
- (4) The contact-breaker points may be dirty or adjusted too closely or too far apart at the "break."
- (5) Ignition timing incorrect by an appreciable angle.
- (6) High-tension coil faulty, e.g. a break in the primary or secondary coils.
- (7) With coil ignition systems failure to start may be due to a run-down battery.
- (8) Sparking plug gaps too great or plug points bridged by oil or moisture.

If engine fires but runs erratically, it should first be ascertained by examination and adjustment that the carburettor is not at fault. Otherwise the cause will probably be one of the following.

- (1) Defective or dirty sparking plug or electrodes too far apart.
- (2) Broken or cracked high-tension cables, causing short-circuiting to earth.
- (3) Dirty contact-breaker points.
- (4) Faulty high-tension cable connexions to distributor or sparking plugs.
- (5) In magneto systems weak magnets, dirty, worn, or broken carbon brushes or commutator segments will cause irregular operation.
- (6) Faulty earthing of coil ignition unit.

Loose cable connexions to the contact-breaker, ignition switch, high-tension coil or the distributor unit and sparking plugs may be another cause of irregular firing.

To test for a faulty sparking plug, when intermittent firing occurs, each of the plugs in turn should be short-circuited, using a screwdriver with an insulated blade (Fig. 194). If the plug short-circuited is a good one, then the speed of the engine will be reduced appreciably, but

in the case of the faulty plug it will make no difference to the engine speed.

Another method is to remove the plugs from the cylinder block and lay them on the top of the cylinder head after

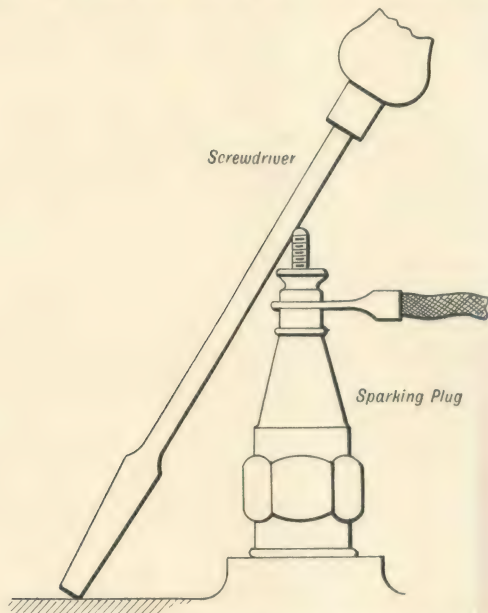


FIG. 194. TESTING FOR FAULTY SPARKING PLUG

connecting up their high-tension cables. The plug points should be watched when cranking the engine; the good plug will give an intense blue spark whereas the faulty one will give either a faint spark or no spark at all. The neon tube tester (Fig. 195) enables the plugs to be tested while the engine is running; it gives a bright glow if the plug is sparking satisfactorily.

Yet another method is to substitute a known good plug for the suspected one, noting the difference upon the engine performance.

Ignition Fault Finding Table. The table on pages 213 and

214 is given for the purpose of locating and remedying faults in coil ignition systems of the Lucas type. With its aid a systematic examination can be carried out and the exact cause of the trouble readily ascertained.

Timing the Ignition. After a general overhaul, or a long period of service the timing of the ignition should be checked and reset if necessary.

With most modern magneto and coil systems having automatic ignition advance, the spark is arranged to occur

COIL IGNITION TROUBLES, CAUSES, AND REMEDIES

SYMPTOMS	POSSIBLE CAUSES	REMEDY
<i>Engine will not fire.</i>	<i>Battery discharged.</i> Starter will not turn engine and lamps do not give good light.	Start engine by hand. Battery should be recharged by running car for a long period during daytime. Alternatively recharge from an independent electrical supply.
	Controls not set correctly for starting.	See that ignition is switched on, petrol turned on, and everything is in order for starting.
	Test if coil sparks by removing lead from centre distributor terminal and hold it about $\frac{1}{2}$ in. away from some metal part of the chassis while engine is turned over. If sparks jump gap regularly, the coil and distributor are functioning correctly.	Examine the sparking plugs, and if these are clean and the gaps correct, the trouble is due to carburettor, petrol supply, etc.
	If the coil does not spark, the trouble may be due to any of the following causes— <i>Fault in low-tension wiring.</i> Indicated by (1) No ammeter reading when engine is slowly turned and ignition switch is on, or (2) No spark occurs between the contact points when quickly separated by the fingers when the ignition switch is on.	Examine all cables in ignition circuit and see that all connexions are tight. See that battery terminals are secure.
	<i>Dirty or pitted contact points.</i>	Clean with fine carborundum stone or fine emery cloth and afterwards with a cloth moistened with petrol.
	<i>Contact-breaker points out of adjustment.</i> Turn engine until contacts are fully opened and test gap with gauge.	Adjust gap to gauge.

COIL IGNITION TROUBLES, CAUSES, AND REMEDIES—(contd.)

SYMPTOMS	POSSIBLE CAUSES	REMEDY
<i>Engine misfires.</i>	<i>Dirty or pitted contact points.</i>	Clean with fine carborundum stone or fine emery cloth and afterwards with a cloth moistened with petrol.
	<i>Contact breaker points out of adjustment.</i> Turn engine until contacts are fully opened and test gap with gauge	Adjust gap to gauge.
	Remove each sparking plug in turn, rest it on the cylinder head, and observe whether a spark occurs at the points when the engine is turned. Irregular sparking may be due to dirty plugs or defective high-tension cables. If sparking is regular at all plugs, the trouble is probably due to engine defects.	Clean plugs and adjust the gaps to about 20-thousandths of an inch. Replace any lead if the insulation shows signs of deterioration or cracking. Examine carburettor, petrol supply, etc.

when the piston of the cylinder under compression is on its top dead centre.

In the case of magnetos having hand-controlled ignition

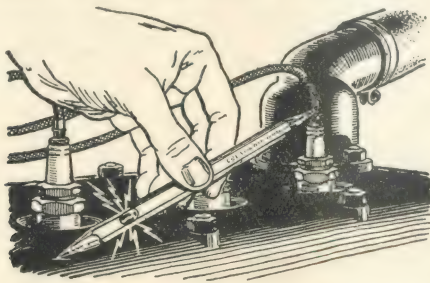


FIG. 195. NEON TUBE SPARKING PLUG TESTER

advance, the lever should be fully retarded, after disconnecting the engine drive to the magneto; it may be necessary to use a sprocket withdrawal tool for this purpose (Fig. 196). The piston of No. 1 (front) cylinder is then set on its top dead centre compression stroke. Next, the armature shaft is turned by hand in its usual working

direction until the contact-breaker points just commence to open and the distributor arm is nearly opposite the brass segment to which the sparking plug cable of No. 1 cylinder is attached ; this ensures the correct cylinder being timed.

Finally, the magneto drive should be coupled up, without in any way disturbing the positions of the engine and armature shaft. The ignition timing will then be correct.

The method generally employed for coil ignition systems

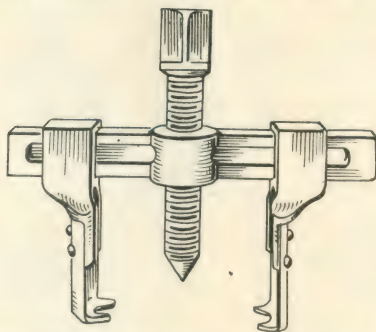


FIG. 196. MAGNETO SPROCKET WITHDRAWAL TOOL

is to loosen the clamp holding distributor unit to engine bracket (Fig. 197). No. 1 piston is set on its top dead centre and the whole distributor unit (with h.t. cover removed so as to enable contact-breaker to be seen) is then moved slowly round its engine drive shaft until the contacts are just about to open. The distributor arm (Fig. 198) should be opposite the cable connexion to No. 1 cylinder to ensure that the spark occurs in No. 1 and not in any other cylinder. Finally, the clamp should be securely tightened.

When timing the engine, any drive backlash must be allowed for.

In some instances, a fine adjustment, e.g. the micrometer method, is provided so that the timing can be set very accurately. This device is useful for resetting the ignition timing should a low-grade fuel be used instead of a high grade or anti-knock one ; in this case the *ignition should be retarded*. Similarly, if the engine combustion chamber

has a layer of carbon deposit causing a "knock" on hills or when accelerating on top gear from a low speed, etc.

In most instances the best ignition timing position is selected to suit the design and condition of the engine, some requiring a little more advance and some less.

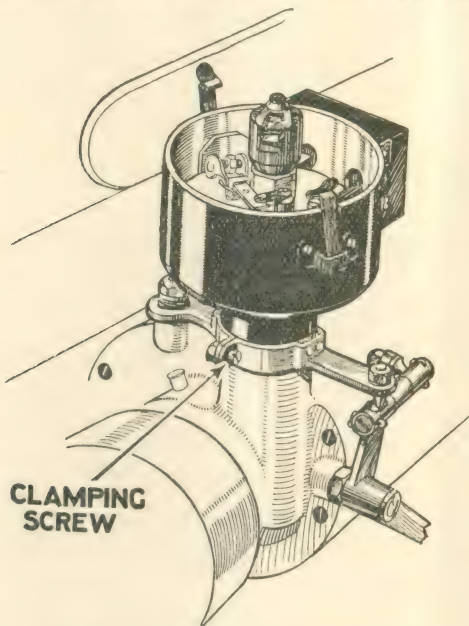


FIG. 197. TIMING THE COIL IGNITION

With automatic advance systems using the centrifugal action due to pivoted weights, the best average position is to time on the top dead centre; improved results can usually be obtained if a hand control is fitted to alter this zero position, however.

CARBURATION CONSIDERATIONS

When adjusting or tuning up engines after an overhaul, the carburettor should receive a certain amount of attention. Since, however, each make of carburettor has its

own special characteristics and methods of adjustment, the makers' instruction literature should always be consulted for adjustment and tuning instructions.

It may, however, be necessary to dismantle and clean the various parts of any carburettor before replacing it on

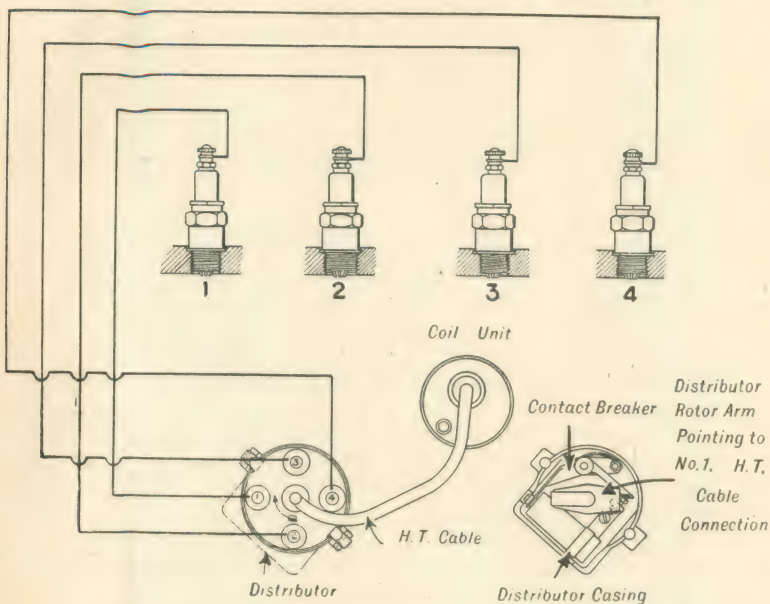


FIG. 198. FOUR CYLINDER COIL IGNITION DIAGRAM

the engine. The float chamber, the jets, control devices and mechanism, and the fuel filter should be cleaned carefully.

After replacing a carburettor, connect up its controls, e.g. the throttle and choke, and then test whether each control operates properly from the driver's seat; this will ensure that the controls are not wrongly connected. The petrol should then be turned on and the petrol pipe unions examined for leakages. If a petrol pump is fitted, this should also be checked for operation and freedom from leakages.

When the petrol is turned on, make sure that none leaks from the float chamber or jets; otherwise this is a sign that

there is dirt under the float needle or that the level of the petrol is too high in the float chamber.

A *punctured float* will also cause an overflow of petrol, evident as a constant dripping from the carburettor.

When a carburettor is dismantled for cleaning, the working members, e.g. the float needle mechanism, sliding parts, valves, etc., should be examined for signs of wear and any excessive wear should be corrected.

Tuning the Carburettor. Generally, the makers' recommendations in regard to jet sizes and choke sizes should be followed, since these have been ascertained as a result of actual tests to be the most suitable for the particular engine.

Where this information is not available, or in circumstances in which a different type of carburettor is fitted to any make of engine, the engine's performance must be used as the basis for tuning the carburettor. The latter should be fitted with any available main and compensating jets of likely size and the engine then tested for acceleration and power, disregarding for the time being the slow-running device.

If the main jets are too small, the mixture strength will be on the weak side and the engine will be sluggish in performance, slow to accelerate, and will not give its maximum revolutions under load.

Popping back through the carburettor air port or hesitancy in picking up speed when the accelerator is depressed is a sign of too weak a mixture.

If, on the other hand, the jets are too large, the mixture will be too rich, and not only will the engine tend to become sluggish in action, but the petrol consumption will be excessive. If the mixture is far too rich, black sooty smoke will be ejected from the exhaust pipe—as when an engine is run with the air choke closed. Overheating will also occur.

For the best power results a carburettor must be tuned so as to give a slightly richer mixture than the one for complete combustion of the fuel. Thus, whereas the correct proportions of air to petrol by weight are usually about 15:1 for perfect combustion of the petrol, a mixture of about 12:1 to 13:1 will give about 15 per cent more power,

while one of 17:1 will give the best fuel economy, i.e. mileage per gallon.

The effect of too small a choke is similar to that of too large a jet, while too large a choke has the effect of weakening the mixture.

Road tests may be carried out to test the settings of the carburettor, the maximum power output being determined

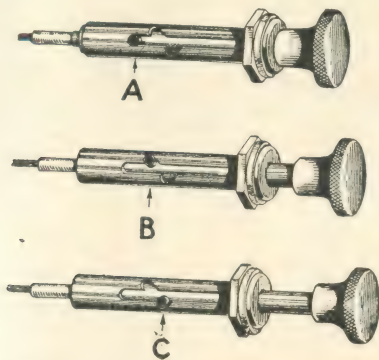


FIG. 199. CARBURETTOR AIR CHOKE CONTROL POSITIONS

- A = Fully open for normal hot engine running
- B = Cold idling position
- C = Closed for starting from cold

by the settings which give the highest road speed on the level, or the best top gear hill climbing results. A check should be kept on fuel consumption, however, for—as previously mentioned—the maximum power output necessitates a richer mixture than the correct one.

Slow running adjustment in the case of most carburetors is effected by (1) alteration of mixture strength of the pilot jet and its air supply, and (2) adjustment of the carburettor throttle stop position.

Usually, means are provided to vary the quantity of air admitted to the slow-running device and a screw stop is arranged to limit the closing position of the main throttle so as to admit just enough mixture past the throttle to keep the engine ticking over, or “idling” at a slow speed. If these adjustments have not the desired effect the most

likely cause is that of *air leakages along the valve guides* or past the carburettor or inlet manifold joints.

The air choke operating control should be adjusted so that it practically shuts off the main air supply for cold starting purposes, but—when released—leaves the air supply unthrottled in any way (Fig. 199).

An engine should never be run for long with the air choke closed or nearly so, or excessive engine wear may occur, owing to the effect of the petrol in reducing the lubricant on the cylinder walls.

The working joints of the carburettor controls and of any mechanism associated with the carburettor itself, should be given a spot or two of engine oil periodically, to ensure free operation.

CHAPTER XIII

ENGINE TROUBLES AND THEIR CAUSES

THE troubles most likely to occur in connexion with motor vehicle petrol engines have been classified and are given in a convenient form in the following summary of engine troubles and their causes.

1. Engine Refuses to Start

Probable Causes

- (1) No petrol or petrol tap shut.
- (2) Ignition failure (run-down battery may be the cause in coil-ignition systems).
- (3) Carburettor controls incorrectly set.
- (4) Sparking plugs oiled or sooted up; or points bridged with liquid petrol.
- (5) Seized engine due to lubrication failure or broken component.
- (6) Cracked cylinder head.
- (7) Blocked up exhaust outlet.*

2. Engine Runs Erratically

Probable Causes

- (1) Carburation imperfect owing to dirt or water in jet; wrong size of jet; air choke control left in operation; petrol shortage in tank or choked petrol filter.
- (2) Faulty ignition, e.g. one or more sparking plugs misfiring; dirty contact points; short-circuiting of an h.t. cable.
- (3) Broken or stuck-up valve; broken valve spring; no valve stem clearance.
- (4) Incorrect valve timing.
- (5) Ignition timing too far advanced or retarded.
- (6) Excessive carbon deposit causing occasional pre-ignition under partial or full-load conditions.

* An occasional cause is when a car with projecting exhaust pipe has been backed into a bank of earth and the pipe end thus becomes blocked with earth.

- (7) Inadequate lubrication to cylinder walls, etc.
- (8) Compression leakage at sparking plug joints or past pistons.
- (9) Dirty silencer; partly choked with soot.
- (10) Overheating, due to radiator and cooling system having little or no water; choked radiator tubes; slack fan belt; water pump failure.
- (11) Air leak between carburettor and inlet manifold.

3. Engine Runs Uniformly but Gives Poor Performance in Car

Probable Causes

- (1) Excessive carbon deposit.
- (2) Valve stem clearances too great; pitted valve seatings.
- (3) Ignition too far advanced or retarded.
- (4) Carburettor requires tuning or controls adjusted.
- (5) Overheating due to lack of water in cooling system; slipping belt; or to (1) or (3).
- (6) Poor compression due to cylinder or piston ring wear; compression leakage at valves or sparking plugs, etc.
- (7) Slipping clutch.
- (8) Brakes binding in their drums. Hand brake may be "On."

4. Engine Will Not Run Slowly

Probable Causes

- (1) Sparking plug gaps too large or contact breaker points opening too small.
- (2) Carburettor slow running device faulty.
- (3) Valves not seating properly.
- (4) Air leakages into induction system past inlet or carburettor gaskets or along valve guides and stems.
- (5) Battery run down (with coil ignition units).

5. Engine After Running Uniformly Stops Suddenly

Probable Causes

- (1) Shortage of petrol. Test float chamber for petrol supply.
- (2) Ignition failure (see page 213).

- (3) Seized piston or bearings, due to oil shortage.
- (4) Pre-ignition due to overheating, lack of water in cooling system or ignition too far retarded.
- (5) Defect in transmission causing locking of same.
- (6) Exhaust pipe blocked.

6. Banging Noise in Silencer

Probable Causes

- (1) Exhaust valve not seating, or sticking in its guide.
- (2) Warped exhaust valve seating.
- (3) Mixture too weak or too rich.
- (4) Occasional misfiring in one or more cylinders.
- (5) Air leaks into silencer through faulty manifold or exhaust pipe joints.

If the engine "bangs" in silencer when car is coasting down hill with ignition switched on, this indicates that the throttle does not close properly and thus allows mixture of a weak nature to get into the cylinders. This slow-burning mixture is still burning when the exhaust valve opens and thus causes explosions in the silencer.

7. Engine Runs Hot

Probable Causes

- (1) Insufficient water in cooling system.
- (2) Partly blocked radiator.
- (3) Fan belt too loose, or belt broken.
- (4) Carburettor adjustment incorrect. Mixture much too weak or too rich.
- (5) Ignition timing too far retarded.
- (6) Excessive carbon deposit in cylinder heads.
- (7) Tappet clearances incorrect.
- (8) Brake or brakes may be binding, e.g. hand brake lever left "On."

8. Engine Knocks Under Load

Probable Causes

- (1) Big-end bearings worn appreciably.
- (2) Small-end bearing clearances too great.
- (3) Excessive carbon deposit.

Loose big-end bearings are usually most pronounced at medium speeds. The particular cylinder in which the knock

occurs can be located by cutting out the ignition of each cylinder in turn, using a screwdriver blade to short-circuit its plug. When the plug is again allowed to fire, a more pronounced knock will then be heard.

Worn small-end bearings are more noisy at low engine speeds and the sounds are of a higher pitch and more

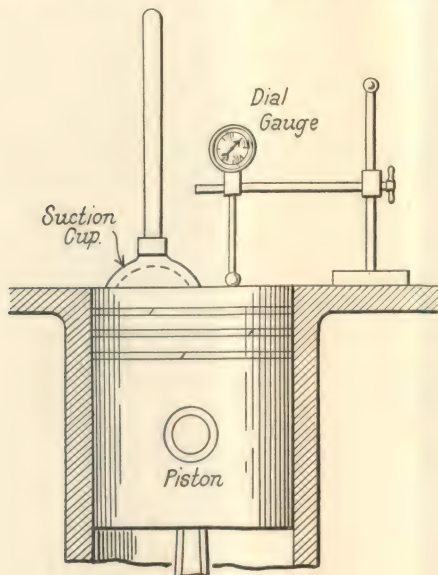


FIG. 200. TESTING FOR BEARING WEAR

metallic than those coming from a worn big-end bearing. Moreover, the sound is not cut out completely by short-circuiting the plug.

If the sparking plugs are removed and the crankshaft is rocked by hand with the cranks, on the bottom centre, in turn, a distinct knock will be heard if the big-end bearings are worn.

Another method of *testing for small- and big-end wear* after the cylinder head has been removed, is illustrated in Fig. 200.

For the purpose of this test, an engineer's dial gauge and

a rubber suction cup mounted on a piece of wooden rod are required. The suction cup is attached securely to the top of the piston and is then pulled up and released, the dial gauge readings showing whether there is any vertical movement of the piston. The latter must be on its top dead centre for this test. The difference between the dial gauge readings obtained by the method outlined gives the sum of the clearances in the small- and big-end bearings.

If, now, the engine sump is removed and the connecting-rod is held firmly down on to the crank pin and the test is repeated, the clearance of the small-end bearing only will be measured, so that by taking this clearance away from the sum of the two clearances previously obtained, the actual big-end clearance is given.

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